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PC GAMER
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Protecting Rights and Promoting Freedom on the Electronic Frontier

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GEOMETRIC FUTURE

UNEARTH THE FULL STORY BEHIND THE LEGEND OF ZELDA

Explore every game in the series and what makes each one so great. If you're a fan, you'll enjoy the trip through time. If you're a newcomer, we offer you this sage advice: "It's dangerous to go alone, take this!"

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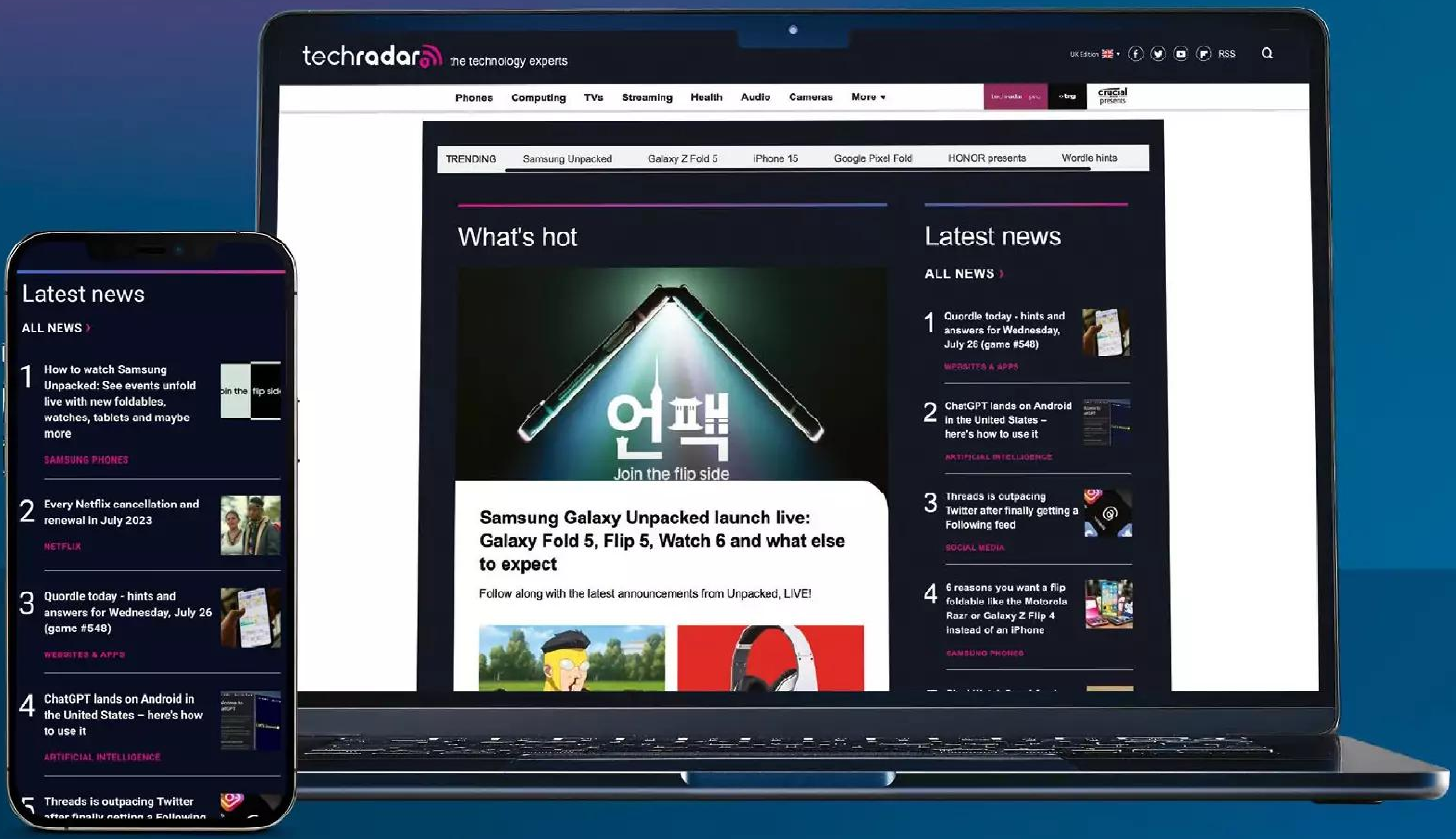
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Next Issue On Sale December 31, 2024

EXTRA DIGITAL FEATURES

AUDIO FILE
PHOTO GALLERY
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Guy Cocker

DELIVERING THE INTEL

IT MAY BE GREEN on the cover of this issue in honor of the colorful Geometric Future Model 5, but inside these pages, it's very blue. That's both a reference to Intel's corporate color, with the new Core Ultra chips leading our cover build and the reviews section, but also the sense of malaise that's greeted this new generation of CPUs. Judged in isolation, Intel's new chips are powerful and very efficient. But when you stack them up against the previous 14th-gen chips, which are more powerful and a lot less expensive than their upgrades, they're quite difficult to recommend.

As Zak says in the conclusion to his build, the construction of these chips is a huge overhaul for Intel—handing manufacturing mostly over to TSMC, moving to a 3nm node, and eliminating hyperthreading. We hope that Intel will figure out a way to eke more out of these chips over time, although our writer Jeremy Laird is dubious (see page 72). For now, a new generation is a chance to update our benchmarks, particularly as this is Intel's first desktop chip with an AI-friendly NPU. A new chip also means a new generation of motherboards, so we've been able to try out the new Z890 Maximum Hero from Asus' ROG range, and all of the dazzling interconnects that come with it.

In the here and now, though, this issue is peppered with advice to take advantage of the bargains available on what is now last-gen tech, from the blueprints at the back of the magazine (page 96) to the questions answered in our letters section (page 94). It's not as cut and dried as we'd like, thanks to concerns about microcode issues with Intel's 13th and 14th-gen chips, but there's never been a better time for the price-conscious PC builder to upgrade.

As this is our Holiday issue, we also have our annual Gear of the Year awards. There were an astonishing number of 'Kick Ass' scores given out in 2024 (18, to be precise), so these are what we've focused on, meaning a product had to be something special to be featured. There are quite a few chassis and SSDs, but the rest of the list is an eclectic mix that includes peripherals, portables, and even a projector. I won't spoil the whole thing—head to page 32 to discover the best PC tech of the year.

Laptop users, we've not forgotten about you, either—may I direct your attention to our integrated graphics shootout on page 44. Non-gaming laptops have gotten pretty good of late, so our graphics expert Jarred Walton has put them through an exhaustive benchmark suite. If you read his piece, you should know what graphics options to look for on your next portable PC, as well as what games you can play once you've finished those spreadsheets.

We didn't quite manage to squeeze in a review of the new AMD Ryzen 7 9800X3D this issue, but we should have it in our build next issue alongside our full review. Early indications (which you can read about on pages 8 and 11) are that AMD's gaming-focused chip is a little more exciting than the other 9000-series launches, with some real gains to be had.

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's editor-in-chief. He built his first gaming PC in 1997 to play Tomb Raider *on 3dfx, and has been obsessed with all things PC ever since.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

AMD Ryzen 7 9800X3D sells out instantly

The latest chip excels, then flies off the shelves

AMD'S NEWEST generation of 3D V-Cache enabled processors is here, debuting with the Ryzen 7 9800X3D. The latest chip is based on the company's 'Zen 5' architecture, and boasts eight cores, 16 threads, and 104MB of total cache.

The CPU deploys AMD's second-generation 3D V-Cache technology, which stacks 64MB of cache memory on top of the processor die. This means the physical cores are closer to the integrated heat spreader instead of being separated by the cache. In theory, this can improve thermal transfer from the cores to CPU's cooling solution, allowing them to better dissipate heat. If configured correctly, the CPU power limit can be increased, as well as core clock frequencies.

While performance gains are an obvious result, this time the generational jump is in the single digits: AMD claims an eight percent boost compared to the preceding 7800X3D chip.

The X3D series has drawn praise for superior gaming performance, but lags behind competitors in content creation. The 7800X3D had scheduling issues due to only having extra cache on one CCD. Early reviews indicate that AMD has heeded these concerns, and made the 9800X3D better rounded.

In November, the CPU was put through its paces by PugetBench. Tests using applications like Blender and Cinebench showed that AMD's latest CPU scored close to the 12-core 9900X series. However, it only beat the 9900X in Photoshop, so the latter is probably better value.

AMD's promised performance boost over its predecessor seems to be an average. During PugetBench's benchmarks of motion graphics using Adobe After Effects, the 9800X3D was five percent ahead of the AMD Ryzen 7 9700X. It was three percent behind the 9900X.

During tests of CPU rendering in Cinebench, initial results show that the 9800X3D lagged well behind the 9900X (31 percent), and was only 10 percent better than the 9700X.

Blender and V-Ray also showed similar results, presumably because both scale well with core count, but don't make use of the CPU's additional cache. Reviewers have been quick to point out, however, that this has limited real-world consequences.

This means that while the 9800X3D may not be the last word in content-creation focused CPU, it can offer solid gaming performance without the cost of lost productivity.

The gaming community felt the same way. The Ryzen 7 9800X3D was made available on November 7 for $479. However, within minutes, the stock held by popular retailers like Amazon, BestBuy, and NewEgg was sold out.

This was in contrast to Intel's Core Ultra 200S (Arrow Lake) series. Despite launching on October 24, by the end of the month, Germany's biggest PC components online retailer, MindFactory, sold no units.

Typically, when new CPUs are released, only a limited initial batch of units is made available. For example, Germany's three biggest online PC retailers are reported to have received only 1,000 Ryzen 7 9800X3D CPUs each.

Reseller prices are typically between $600 and $700—an average increase of over 25 percent on the recommended retail price of $479. The situation is little better in Germany, with prices as high as €699 (around $750).

Scalping isn't confined to this particular CPU, or even AMD chips. Despite an original MSRP of $589, the Intel Core Ultra 9 285K can be found for up to $1,299 on eBay. Like the 9800X3D, Intel's CPU also sold out quickly on the first day of its launch in late October. Such shortages are common. If PC builders exercise patience, they can make serious savings instead of being price gouged.

As for whether AMD's 9800X3D is worth purchasing, most reviews agree that its strengths lie in gaming. This is due to the CPU lagging behind Intel chip's significantly when it comes to benchmarks like content creation, as well as workstation performance and encoding. Expect our full review in the next issue. **–ND**

> “The 9800X3D offers a respectable performance boost over its predecessor

AMD
RYZEN
AMD 3D V-CACHE™ TECHNOLOGY
AMD
RYZEN
7
AMD
RYZEN
9000 SERIES PROCESSOR
7

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NVIDIA UPGRADES (AND DOWNGRADES) GEFORCE NOW

MID-TIER RES BOOSTED, BUT PLAYTIME CAPPED

DUE TO ITS NEAR total dominance of the AI chip sector, Nvidia is now the most valuable company in the world, valued at over $3 trillion. However, that doesn't mean that the company's cloud gaming division is going to be immune to a little penny-pinching.

In November, GeForce Now announced a 100-hour monthly cap on gameplay. This will take effect after January 1 2025 for new subscribers, and from January 2026 for all users. Nvidia claims this will "provide exceptional quality and speed—as well as shorter queue times", and that the time limit will accommodate 94 percent of players. The other six percent can purchase more time.

There are some perks for 'Priority' subscribers, which has been renamed 'Performance'. The 1080p cap has been abandoned in favor of 1440p and ultrawide resolution streaming, and the subscription price remains at $9.99 per month. **–ND**

INTEL'S BATTLEMAGE GPUS: DECEMBER DEBUT?

Launch could shake up budget GPU market

Intel's previous Arc series had driver compatibility issues.

IN A POST ON CHINESE SOCIAL MEDIA site Weibo, hardware leaker Golden Pig has claimed that Intel's new line of 'Battlemage' GPUs will be released in December.

If true, this means that the GPUs will arrive ahead of Nvidia's RTX 5000 series. From a marketing perspective, releasing the Battlemage series around the Black Friday sales makes sense. This would also give Intel a clear runway before any new announcements from competitors at the upcoming CES trade show in January 2025.

The rumors seem to indicate that Battlemage GPUs will offer comparable performance to mid-range cards like NVIDIA's GeForce RTX 4070.

Though Golden Pig has made accurate predictions before, a 2024 release of the Battlemage series has been teased for some time. Back in June, Intel even announced that its Xe2 architecture would be deployed in the GPUs. **–ND**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **MASS EFFECT TV SHOW IN 'ACTIVE DEVELOPMENT'**
Details are scarce on Amazon's adaptation, but *Fast 9* writer Daniel Casey is on script duties.

✓ **STEAM INTRODUCES GAME RECORDING FEATURES**
Background recording, quick replays, and 'timeline-enhanced' markers are now present.

✓ **COPILOT PRO ADDED INTO MICROSOFT 365**
Users no longer need to pay $20 for the add-on.

TRAGEDIES

✗ **GTA 6 FOR FALL 2025**
Rockstar's parent company Take-Two confirms only PS5 and Xbox Series S/X versions.

✗ **MICROSOFT ACCUSED OF SLOWING DOWN CONTROL PANEL FEATURES**
This raises questions about Microsoft's past practices.

✗ **HACKER ALLEGEDLY STEALS FROM NOKIA**
Despite Nokia's denials, threat actor 'IntelBroker' has offered source code for sale .

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GOOGLE LEAKS PREVIEW OF JARVIS AI

The new assistant can take control of Chrome

JARVIS IS THE name given by Iron Man to one of his AI assistants, in honor of the Stark family butler. Google has seemingly decided to continue this tradition with the codename for its latest AI prototype, which was briefly made available via the Chrome web store in November.

The prototype offered some insights into its upcoming features. According to *The Information*, the version of Jarvis on the Chrome store was an internal preview. It also carried the description, 'a helpful companion that surfs the web with you'. When a reporter installed the extension and asked Jarvis to complete a task, it failed due to access permissions.

Still, the nature of the permissions provided some insight into Jarvis' purpose. Unlike previous assistants, the AI will be able to take full control of someone's computer. The stated goal is seemingly to allow Chrome to browse the web on a user's behalf to book flight tickets or perform in-depth research.

In late October, *The Information* claimed to have spoken with Google insiders, who also confirmed that the AI would be able to respond to user commands by capturing and analyzing screenshots of their activity. Google has yet to detail what user data will be gathered, or how it will be processed.

The extension was taken down from the web store later that day. Currently, the initial stable release is anticipated in December. This would dovetail with Anthropic's Claude AI assistant, which will enter the beta stage of testing next month. Like Jarvis, Claude has a feature that can examine the screen, as well as simulate mouse movement and typing.

The control such assistants would have raises privacy concerns. In the Avengers movies, JARVIS was compromised by a malevolent AI, for instance. **–ND**

APPLE UNVEILS MAC MINI M4

The new Mac Mini lineup offers considerable performance improvements

IN A NOSTALGIC stop-motion video released in late-October, Apple showcased its latest Mac Mini offering, describing it as "five by five inches of pure power and purpose."

This is the first major redesign of the miniature PC since 2010. The latest offering is less than half the size of previous models, with a height of two inches and a weight of 1.5lb. The M4 chip is a 10-core CPU and GPU. The base model starts with 16GB of unified memory, presumably to better handle AI-intensive tasks.

The asking price is $599, which also includes a rather miniscule 256GB SSD. The port configuration along the back of the unit is similar to the Mac Mini 2. There are three Thunderbolt 4 ports, along with an HDMI and Gigabit Ethernet port.

Unlike previous Mac Mini models, the front now has its own ports: two USB-C and a 3.5mm headphone jack. For some reason, the power button is now on the bottom of the device. There are also no USB-A ports. Still, it all works nicely within Apple's ecosystem, as devices like iPhones and iPads now use USB-C.

Apple fans willing to upgrade to the Apple Mac Mini M4 Pro benefit from Thunderbolt 5 ports, offering data transfer speeds of up to 120 Gbps. The M4 Pro variant also boasts 14 CPU cores and 20 GPU cores. Prices start at $1,399.

The latest Mac Mini supports up to three external displays, though at differing resolutions. The standard Mac Mini M4 supports two 6K displays at a 60Hz refresh rate via Thunderbolt and a third 4K display at 60Hz over HDMI. The Mac mini M4 Pro, however, can run three 6K displays at 60Hz. It can also support one 6K display with either an 8K display at 60Hz or a 4K display at 240Hz in a dual monitor setup.

Given the myriad hardware configurations, it's hard to benchmark the Mac Mini in a consistent way. However, online reviews agree that performance is 30-50 percent faster than the previous M2 model. **–ND**

Valorant has best anti-cheating system

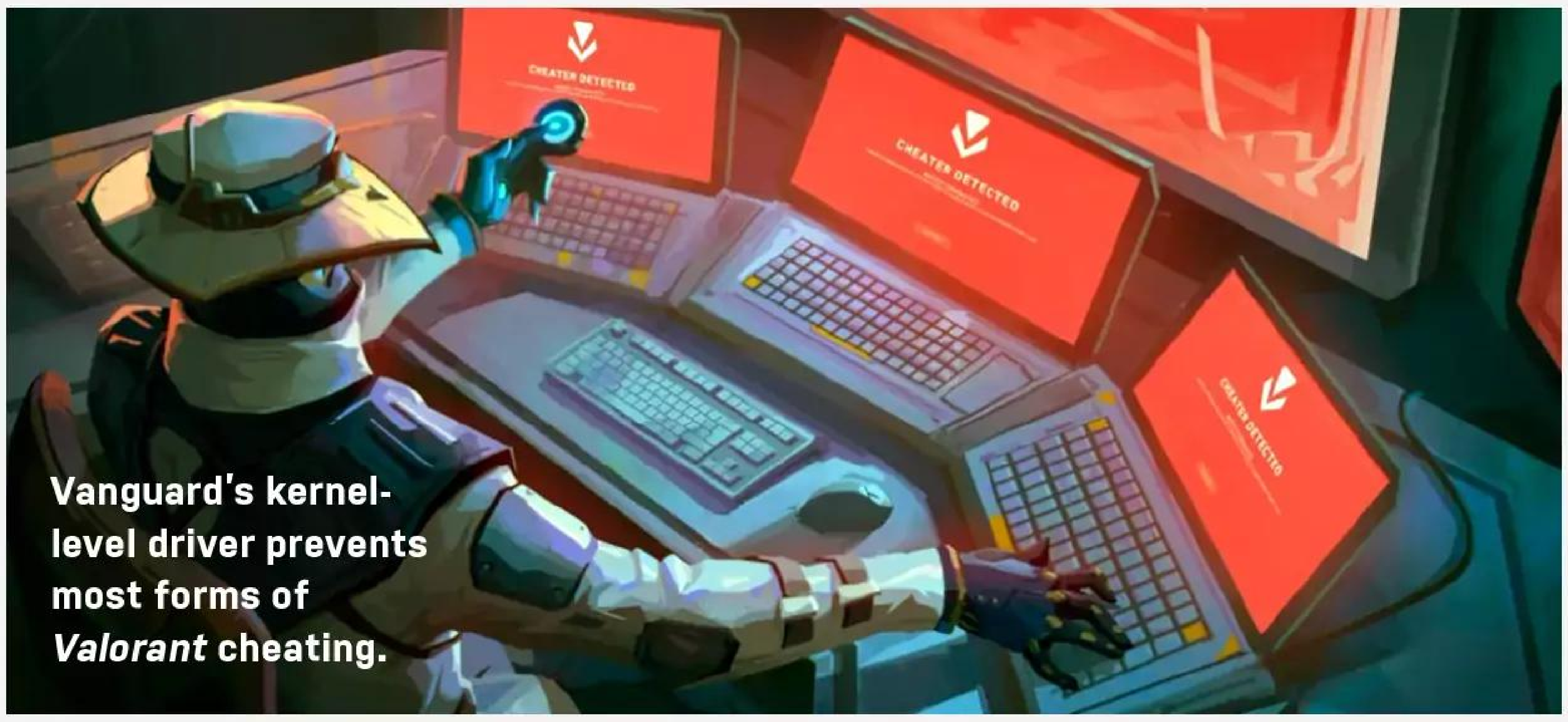
RESEARCHERS AT BIRMINGHAM UNIVERSITY in the UK have declared the anti-cheat system in FPS *Valorant* as the most effective in the gaming industry.

Codenamed 'Vanguard', the system has outperformed competitors like *Fortnite* and *Team Fortress 2*. Valorant's most common cheats center on aimbots to improve firing accuracy. The game also is subject to 'wallhacks', whereby unscrupulous players can render surfaces transparent to give themselves an unfair advantage.

Vanguard's success is mostly down to the kernel-level driver, which runs automatically when the system boots. This allows for easier detection of more advanced forms of cheating, such as unauthorized mappings in kernel memory.

However, it has raised privacy concerns, given that it can run constantly in the background. This said, if players install the latest Windows 11 security updates, it can be configured to launch only with the game.

Cheaters have pushed back with newer methods, such as DMA (Direct Memory Access) tools. These connect the motherboard directly, so can access a game's virtual memory without going through the CPU. Vanguard is working on restrictions to implement Input-Output Memory Management Unit (IOMMU). This is already used in consoles like the PS5 to prevent memory manipulation. **–ND**



Vanguard's kernel-level driver prevents most forms of *Valorant* cheating.

Microsoft brings AI rewriting tool to Notepad

Notepad has received its first major upgrade since the '80s. The 'Rewrite' feature is currently available via Windows Insider development builds in some countries, and can be installed in stable versions of Windows via Powershell.

Rewrite works by using generative AI to rephrase sentences, as well as adjust the tone and content of text. These can be adjusted by a range of preferences. For example, 'Tone' options include Default, Formal, Casual, Inspirational, and Humor.

There are also new provisional AI features in Paint. 'Generative Fill' allows users to replace image elements of their choice with AI content. 'Generative Erase' can also be deployed to remove parts of the image, then fill the blank space with an appropriate background. **–ND**

Starcraft Games Added to PC Game Pass

Since launching in 2017, Xbox's game subscription service has grown to over 34 million members. Now, subscribers can access *StarCraft: Remastered* and *StarCraft II: Campaign Collection*, as long as they have the PC version of Game Pass.

Given the franchise stretches back to March 1998, Xbox Wire accompanied the announcement with a post explaining the various factions available, along with an overview of gameplay mechanics.

PC Game Pass includes over 60 missions across the *StarCraft II* campaigns. These include Wings of Liberty, Heart of the Swarm, and Legacy of the Void.

StarCraft: Remastered is an updated version of the original, first released in 2017. Hopefully more Blizzard titles are on the way. **–ND**

© APPLE CORP, RIOT GAMES (VALORANT)

Jarred Walton

TECH TALK

CPU Gaming Showdown: 9800X3D vs Core 9 285K

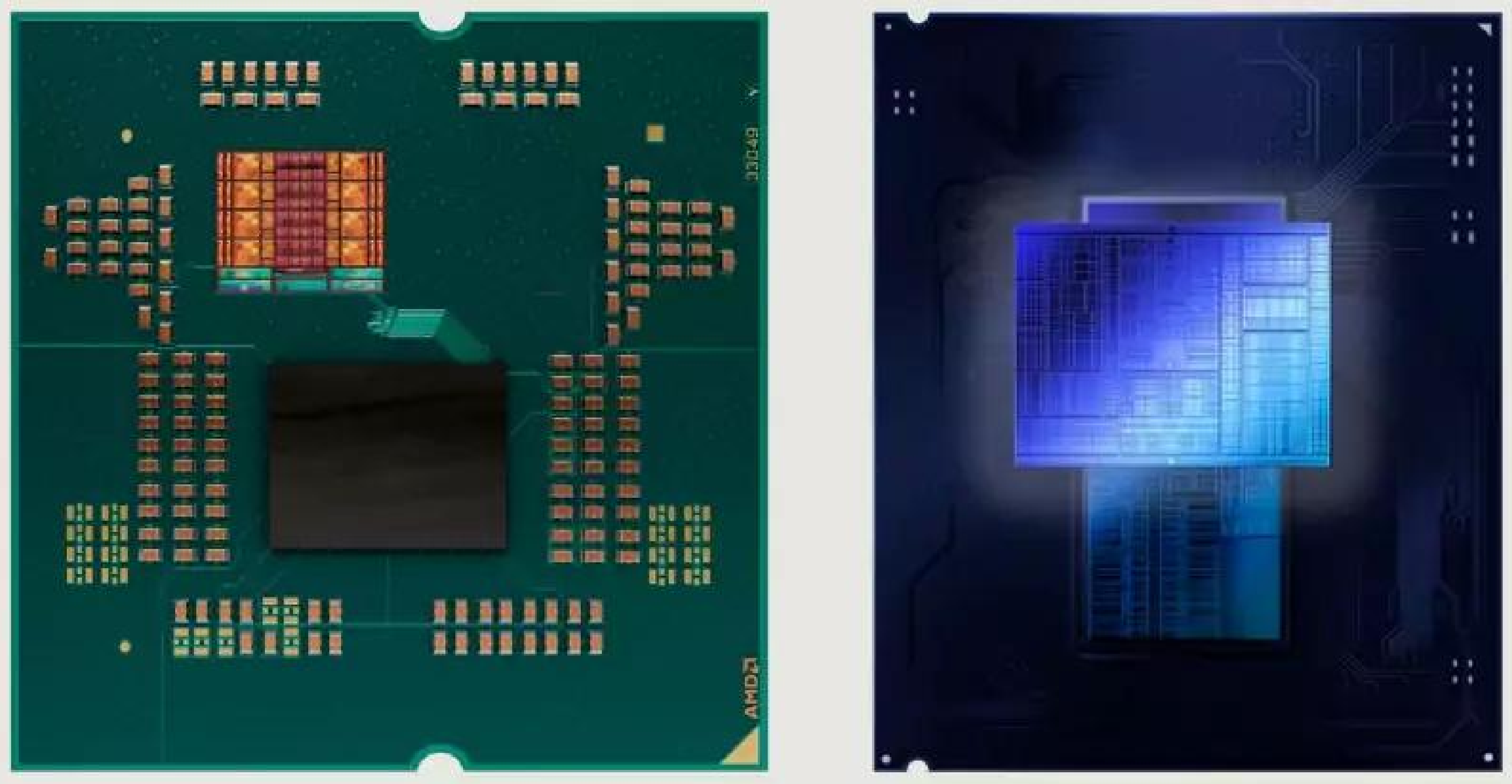
THE PAST MONTH has been both exciting and underwhelming. Intel had a lot riding on Arrow Lake—check our reviews on pages 74 and 76. The third iteration of Intel's desktop CPU architecture, it got an upgrade from the Intel 7 process node used with Raptor Lake to TSMC's N3B. AMD replied with the 3D V-Cache enabled 9800X3D, based on the Zen 5 architecture.

From the sidelines, Arrow Lake sounded like the more impressive design. Multi-tile chips leveraging a variety of manufacturing nodes, with a renewed focus on efficiency? Sounds great. Toss in the new Lion Cove performance cores and Skymont efficiency cores, and it felt like Intel's race to lose. Putting stacked L3 cache on the chips has proven effective in boosting gaming performance, but otherwise, Zen 5 X3D didn't sound that exciting. How wrong that line of thinking turned out to be.

AMD reworked the 3D V-Cache to move the extra die under the main CPU die. This is critical, as the stacked cache acted as a blanket, trapping heat inside the processing cores and limiting top clocks and safe voltage ranges. With the cache under the chips, AMD delivers about a 10 percent gen-on-gen improvement in real-world CPU clocks. Coupled with a 15 percent increase in IPC (instructions per cycle) from the new architecture, and the Ryzen 7 9800X3D could deliver up to 25 percent higher performance than the 7800X3D.

Contrast that with Arrow Lake. The design is more reminiscent of the previous-generation Meteor Lake laptop processors, as opposed to this year's Lunar Lake refresh. Both chips use four main tiles, plus the Foveros interposer, while Lunar Lake has two tiles. More critically, Intel made several key changes that hurt performance in latency-sensitive workloads, like gaming.

> Arrow Lake delivers gains in efficiency, and a modest improvement over Raptor Lake



AMD Zen 5 X3D on the left in green, and Intel Arrow Lake on the right in blue (chips not to scale). The relative simplicity of AMD's approach wins out in the end.

The memory controller sits on the IO tile. This was perhaps a cost-saving measure, as external memory interfaces wouldn't scale much with the more expensive N3B process node. But now, all core accesses to system RAM need to jump through extra hoops, and memory latency ends up 15nm slower than on Raptor Lake chips.

If that was the only change, Arrow Lake may have fared better. However, Intel also switched from separate E-core clusters to interspersing the E-cores throughout the CPU tile and sharing the unified L3 cache. There are benefits, like fewer hot spots and higher performance from the E-cores. But E-cores and P-cores run on different clock domains, and with Intel's ring bus interconnect, that creates more issues with latency.

The net result is that Arrow Lake delivers great gains in efficiency, and for applications that aren't as sensitive to latency, a modest improvement over Raptor Lake. But games are usually slower on the new Core Ultra 9 285K compared to the Core i9-14900K, never mind the Ryzen 7 9800X3D.

Arrow Lake feels like AMD's first-generation Ryzen processors: great for multi-threaded workloads, but not when it comes to gaming. Intel has promised firmware updates, which should let the 285K match the 14900K in gaming performance. But depending on the gaming test suite, at 1080p ultra with a fast GPU like the RTX 4090, the 9800X3D may still keep a 25 percent margin of victory. Why didn't Intel put a fat cache on top of the IO tile? Maybe we'll get that with Nova Lake.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

© AMD/INTEL

THE LIST

THE BEST MINI PCS

RECENTLY, mini PCs have bulked up to become modest yet viable gaming platforms. The latest laptop APUs have decent iGPUs for light gaming, but some mini PCs actually have dedicated GPUs. Of course, if you're after high frame rates at 1440p and beyond, then you're better off self-building. But if you're looking for a tiny, off-the-shelf PC with awesome everyday computing power, you've come to the right place.

5

AYANEO RETRO MINI AM02

With its NES-aping design, the Retro Mini AM02 is the cutest mini PC around. Inside lurks the excellent AMD Ryzen 7 7840HS APU, and a level of performance customization that few other machines offer. This gunmetal-gray homage to the original Nintendo Entertainment System also has a front-flap concealing USB and headphone ports, and a touchscreen with system info and access to TDP presets. It's the best-looking mini PC on the planet. **$599, www.ayaneo.com**

4

GEEKOM AX8 PRO

It's actually pretty stunning how much performance you can pull from a PC so darned small. The Geekom AX8 Pro is incredibly dinky, yet the eight-core AMD processor at its heart still delivers some excellent iGPU-based gaming performance without sounding like a jet turbine. The only downside is the price. There's a cheaper version of the AX8 that drops the M.2 storage from 2TB to 1TB, keeps the 32GB DDR5-5600, and replaces the Ryzen 9 8945HS with the Ryzen 7 8845HS. That's a very minor downgrade, and arguably better value. **$899, www.geekompc.com**

3

ASUS ROG NUC 970

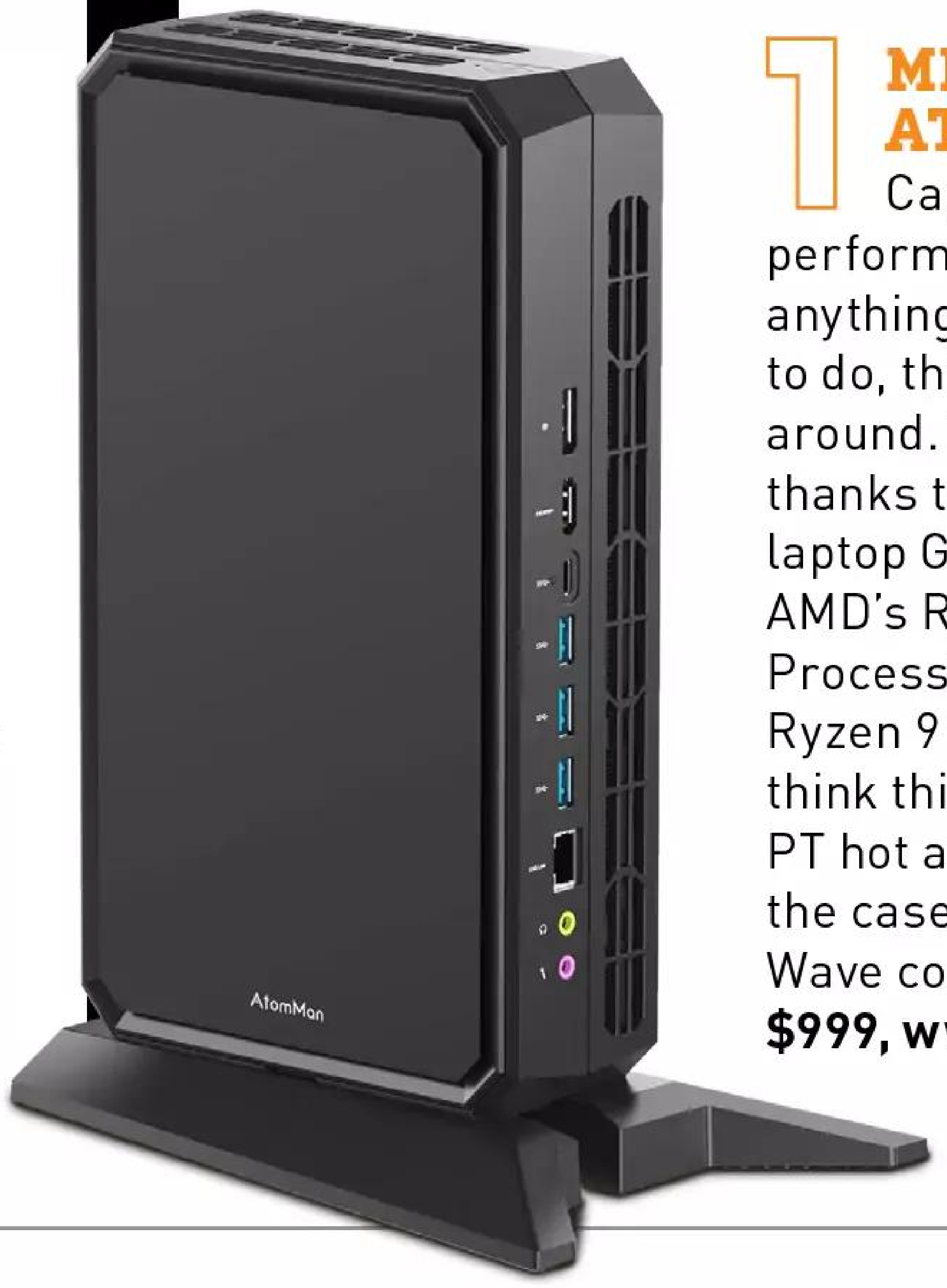
For the best gaming performance, this is the one to covet, but you'll need to part with a lot of cash to call this your own. Then again, you get the most powerful graphics silicon you'll find in such a small chassis: an Nvidia RTX 4070 mobile GPU. CPU-wise, it's fitted with the Intel Core Ultra 9 185H CPU and its six P cores and eight E cores. It can get blowy under load, but that's the price you pay for performance. **$2,199, www.asus.com**

2

MINISFORUM VENUS UM790 PRO

Pick the barebones unit, source your own RAM and storage, and you'll have a cheap, powerful mini PC for both gaming and any kind of other PC work you might care to throw its way. It may be small, but it's got great potential and genuinely impressive cooling. The APU at its heart is AMD's Ryzen 9 7940HS wielding eight cores and 16 threads, which can hit a turbo clock speed of 5.2 GHz, and folds the mighty little Radeon 780M into its design. If you're looking for an inexpensive yet performant mini PC, this is our best budget pick. **$429, www.minisforum.com**

MINISFORUM



1

MINISFORUM ATOMMAN G7 PT

Capable of 1080p gaming performance and practically anything else you might want to do, this is the best mini PC around. That's in no small part thanks to a discrete mid-range laptop GPU in the form of AMD's Radeon RX 7600M XT. Processing is handled by the Ryzen 9 7945HX. You might think this would make the G7 PT hot and noisy, but that's not the case. Minisforum's Cold Wave cooling tech is fantastic. **$999, www.minisforum.com**

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Jeremy Laird

TRADE CHAT

Can Nvidia make Arm chips work for gaming?

THE LATEST WHISPERS claim that Nvidia will put a new SoC into production in September 2025, and that it will be aimed at 'high-end' PCs. Of course, games are the one thing that Arm chips still struggle with. But if anyone can crack that conundrum, it's Nvidia, right?

Allegedly, Nvidia is plotting Arm chips engineered in partnership with MediaTek and fully custom in-house designs. It's the version aimed at consumer PCs that will supposedly be pure Nvidia, while MediaTek will partner with Nvidia to create another Arm-based SoC for enterprise customers.

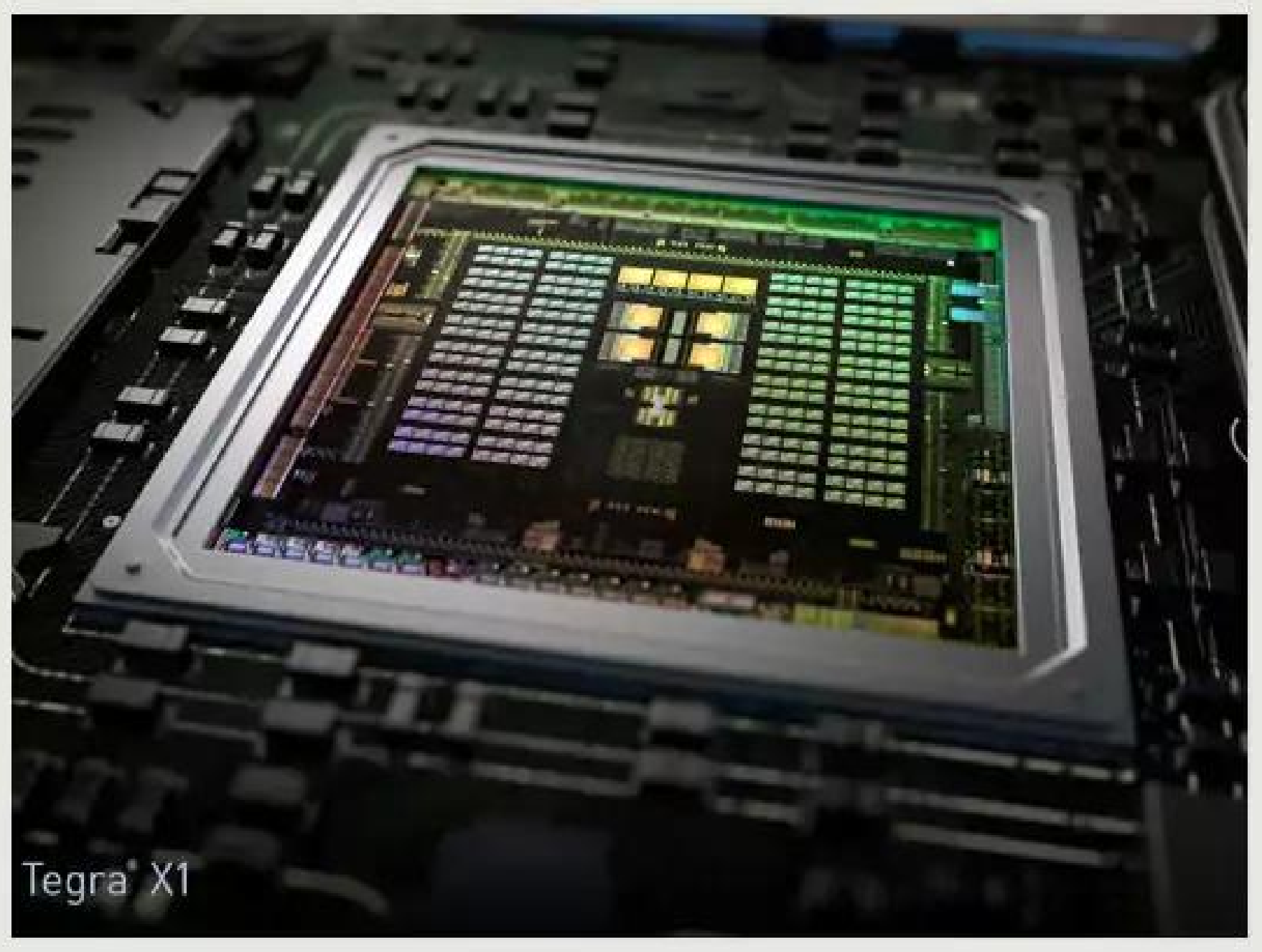
The enterprise chip probably needs 5G connectivity built in, hence the MediaTek tie-up. MediaTek is one of very few outfits capable of building 5G into an SoC, but the consumer PC chip, probably for laptops, maybe for handhelds or even desktops, doesn't have that requirement, giving Nvidia a free hand to design it exactly how it wants.

Anyway, precisely where in the market Nvidia will pitch its this Arm-based newcomer isn't clear. But surely it will lean heavily into Nvidia's utterly dominant graphics technology. After all, if it doesn't, what's the point? There are plenty of alternatives with good CPU cores but unremarkable GPUs.

It feels fair to assume that Nvidia's Arm chip will have the best raw graphics performance on the planet. The unknowns are twofold. First, what will the CPU cores be like? Nvidia has the option of buying in some ready-made core designs from Arm itself. That wouldn't be a terrible option, but equally, it wouldn't be very exciting.

Moreover, Apple has proven that Arm chips can be more than competitive with any of Intel and AMD's x86 cores. The latest Apple M4 CPU cores crank out as much as 60 percent more performance per clock than the best x86 processors.

> Arguably, Nvidia needs to work with game developers to recompile at least some of their catalogs for Arm



Nvidia has produced Arm chips before, but these new SoCs are rumored to be a huge step up.

Nvidia doesn't have a lot of form when it comes to designing CPU cores, but nor did Apple, and you can't doubt the scale of Nvidia's resources or its technical nous. Likewise, Qualcomm has come out of nowhere with its Oryon Arm-based cores in the Snapdragon X chip for PCs, further confirming the ability of the Arm instruction to be competitive. You'd have to give Nvidia a decent shot at creating a seriously competitive CPU.

In that context, the endeavor may hinge on Nvidia's ability to get games running on its new chip. The problem is that PC games are built for the x86 instruction set, not for Arm. PC games are also sensitive to any performance dips or latencies, so while it is theoretically possible to run an x86 PC on a Arm chip through emulation, the results are virtually guaranteed to be suboptimal.

Arguably, Nvidia needs to work with game developers to recompile at least some of their catalogs for Arm. For most companies, this would be a non-starter. It would be too costly, take too long, and the required relationships with the game development industry just wouldn't be there. But Nvidia has the closest ties with game devs of any hardware vendor. Literally every PC game dev optimizes their output for Nvidia graphics.

In other words, if any company is in a position to get a critical mass of games ported to Arm, it's Nvidia. Heck, if it has to fund a lot of the work itself, it can surely afford it, so the notion of the Arm gaming PC has been a long time coming. But it might just arrive next year.

Of course, Nvidia's plans for this chip likely go well beyond gaming. Some commentators think Nvidia has Apple in its sights. Supposedly, Nvidia envies the control and prestige Apple has achieved with its MacBook computers now that they are all running Apple's own in-house silicon, not to mention the revenue. Nvidia wants some of that. How successful it will be is impossible to say, but it will certainly be fun watching it try.

Six raw 4K panels for breakfast, laced with extract of x86… Jeremy Laird eats and breathes PC technology.

© NVIDIA

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

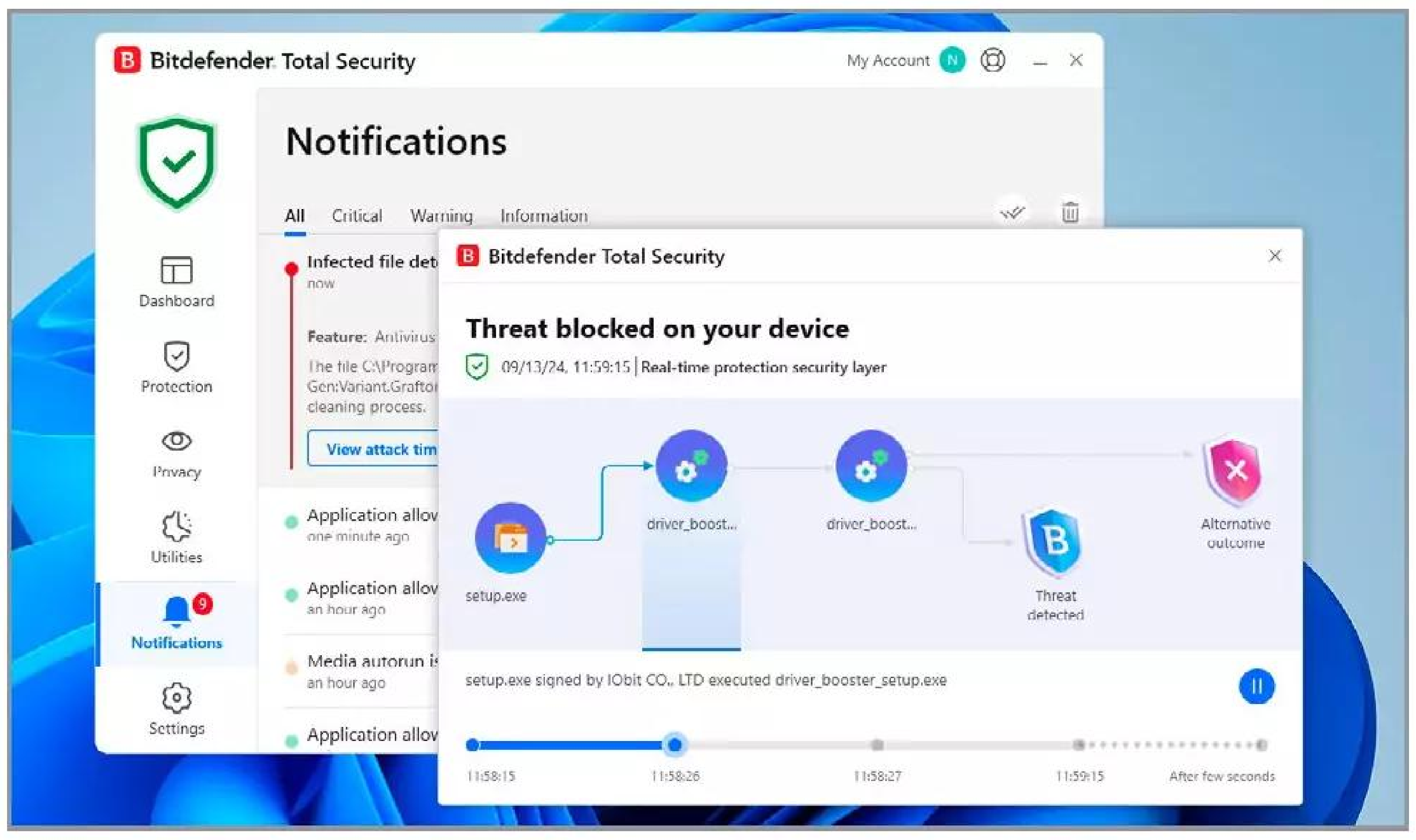
> Move to new PC
> Temp files stuck
> Mask email address

Transfer legacy apps

What is currently considered the best (and easiest) way to migrate programs, settings, and so on to a new PC? I built my last machine back in 2009. Through the years, it has updated from Windows 7 to Windows 11 (with some effort), but has reached its limits. I have some legacy programs that currently work fine, but trying to re-install may not be possible due to the fact that they were supplied on diskettes. Ideally, I'd like to build a brand new machine and clone my existing unit—is that possible? Happy to pay for software. **—David Sollish**

THE DOCTOR RESPONDS: While it might be technically possible to clone your old hard drive and transfer it to your new PC, that will be fraught with difficulties, and likely cause other issues with an aging Windows installation, however good Windows is at reconfiguring and repairing itself when encountering new hardware.

A better option is to investigate software designed to transfer applications and settings, along with files from one PC to another. This means building your new PC and installing a fresh copy of Windows 11, along with the correct drivers for your system. Also, consider installing key software that doesn't require porting over, such as third-party security software, if you use it.


Bitdefender Total Security
My Account
Notifications
All
Critical
Warning
Information
Dashboard
Protection
Privacy
Utilities
Notifications
Settings
Infected file det
now
Feature: Antivirus
The file C:\Program
Gen:Variant.Grafto
cleaning process.
View attack tim
Application allov
one minute ago
Application allov
an hour ago
Media autorun i
an hour ago
Application allov
Bitdefender Total Security
setup.exe
driver_boost...
driver_boost...
Threat detected
Alternative outcome
11:58:15
11:58:26
11:58:27
11:59:15
After few seconds

Threat blocked on your device

09/13/24, 11:59:15 | Real-time protection security layer

setup.exe signed by IObit CO., LTD executed driver_booster_setup.exe

Bitdefender offers to explain why it's blocked a possible threat.

Once your new PC is ready to receive the transfer, you can install the software on both old and new machines. Believe it or not, that software is PCmover from Laplink—yep, it's still the number one choice for migrating apps, settings, and files from one PC to another. Its Home edition ($39.95, https://web.laplink.com/product/pcmover-home) transfers apps, files, and settings, but only works with single-drive or partition systems, so if you've got multiple drives or partitions to transfer, consider its Pro edition ($59.95) instead. The program comes with a 30-day money back guarantee in case it's unable to transfer those legacy apps across. The fact that you'll be transferring from one Windows 11 PC to another should maximize your chances of success.

Temp cleanup fail

I've noticed that Windows 11 is no longer removing all my temporary files when I use Disk Cleanup or the cleanup options in Settings. The offending files appear to be Windows Updates that refuse to shift, and there are around 8GB of them. Can you help me get rid of them? **—Michael A Woods**

THE DOCTOR RESPONDS: This sounds like a new 'feature' in the latest version of Windows 11 (Windows 11 24H2) that's been rolling out across PCs. It's linked to a new approach taken by Windows towards implementing updates, which utilizes a checkpoint system. This takes recently installed updates and marks them as 'baseline' files. These files allow future cumulative updates to be smaller and faster to install, as they're built from these baselines, rather than the older 24H2 RTM release.

The downside is that these components can't be removed from your PC to free up space in the way they used to be. The problem is compounded by the fact that they show up in Windows' various disk cleanup tools, including DISM and the classic Disk Cleanup tool, as well as Settings' own cleanup manager. As a result, you'll see 8.63GB appear under 'Windows Update Cleanup'. The tools will allow you to select this cache for cleaning, but they

© BITDEFENDER

↘ submit your questions to: doctor@maximumpc.com can't remove it, so it'll keep appearing on future scans.

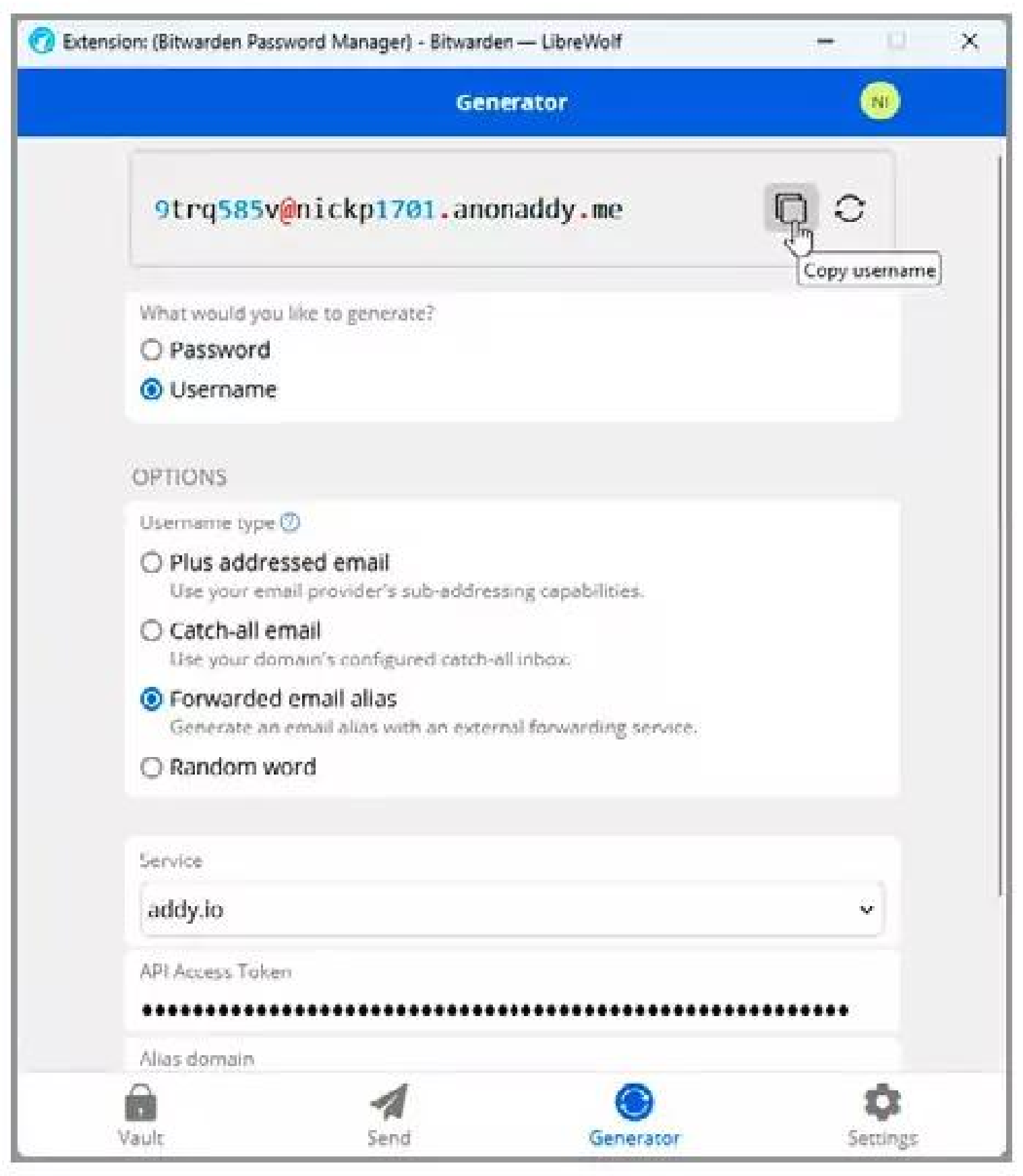
Microsoft is aware of the problem, and says it'll be issuing a fix. On the upside, although the disk cleanup tools claim the cache is 8.63GB in size, it doesn't appear to take up much drive space. We suspect the tools are inflating the figures, so the fix will likely exclude the cache (and files marked within) from future scans.

Link addy.io to Bitwarden

I recently checked my email at https://haveibeenpwned.com and was shocked—if not exactly surprised—to find it had been exposed in multiple breaches. This has led me to realize that it's time to stop giving out my real email address to all and sundry. I've signed up with addy.io to generate fake email addresses that funnel mail to my actual address, and want to link it to my Bitwarden account. This way, I can easily generate new email usernames alongside strong random passwords directly from Bitwarden when signing up to new sites. Can you explain in simple terms how this is done, please?

—Reginald McElfresh

THE DOCTOR RESPONDS: Start by signing into your addy.io account (**https://app.addy.io**)—if you've not already done so, we advise adding 2FA to this account for an extra layer of security. Once done, select Settings from your dashboard, and switch to the API Keys tab, where you'll see a 'Create New API Key' button. Click this to generate a new API key. Give it a suitably descriptive name (Bitwarden being the obvious choice), and choose whether you want the API key to expire after a set date or not (this would mean periodically having to generate a new one). Finally, re-enter your **addy.io** password, and click 'Create API Key'.



Extension: (Bitwarden Password Manager) - Bitwarden — LibreWolf

Generator

9trq585v@nickp1701.anonaddy.me

What would you like to generate?

○ Password

● Username

OPTIONS

Username type

○ Plus addressed email

Use your email provider's sub-addressing capabilities.

○ Catch-all email

Use your domain's configured catch-all inbox.

● Forwarded email alias

Generate an email alias with an external forwarding service.

○ Random word

Service

addy.io

API Access Token

••

Alias domain

Use addy.io with Bitwarden to hide your real email address.

You'll be shown the API key, alongside a QR code—select the code and copy it to the clipboard. Now, switch to Bitwarden and create a Secure Note, inside which you can paste and store the API key (you could also add it as a custom field to your existing addy.io vault entry). You won't be able to view the key from your account again; if you lost it, you'd need to generate a new one.

Once stored in Bitwarden, switch to the Generator section and select Username. Select 'Forwarded email alias' under Options, and 'addy.io' under Service. Paste your API code into the API Access Token field, then fill in the alias domain (it'll be something like yourname@anonaddy.me—check Settings > General tab from your addy.io web dashboard if you're not sure what this is). Leave Server URL blank, then click refresh to generate a new fake email, which will be added to your addy.io account and set to forward to your actual email address. Verify this by checking your addy.io web dashboard, where the fake address should appear.

Bitdefender false positive?

I tried to install IObit Driver Booster on my PC, only for Bitdefender to block the installation. How can I find out more about this? I wasn't aware IObit was linked with malware, so is this a false positive? If it is, how do I stop Bitdefender from blocking the installation?

—Natasha M Bell

THE DOCTOR RESPONDS: The issue here isn't with Driver Booster itself, but one of its components. Thankfully, Bitdefender records plenty of information about threats to help you understand what was blocked and why. To check this, open the Bitdefender window and select Notifications in the left-hand pane. You should see the recent alert appear in the Critical section under 'Infected file detected'. Expand this, and you'll see which file was flagged and the type of threat Bitdefender identified. There's also an attack timeline that provides details of how the attack occurred, and when in the process it was detected and blocked.

The file Bitdefender had identified as being infected in Natasha's case was part of Driver Booster's update mechanism, and it was claimed to be a 'Gen:Variant:Graftor' infection. This indicates that Bitdefender has flagged the file as suspicious based on its behavior rather than any known infection. It's often a false positive—and sure enough, within days, the program installed without flagging an alert.

But just because it's likely to be a false positive, it doesn't mean you should assume it's safe. Bitdefender will allow you to restore flagged items and exclude them from future scans—navigate to Protection, open Antivirus, and switch to Settings to access the quarantine—but it's a good idea to proceed with caution.

After restoring a file from quarantine, submit it to VirusTotal (**www.virustotal.com/gui/home/upload**) to see how it's viewed by over 70 other antivirus scanners. Also, consider submitting the file to Bitdefender as a false positive—visit **www.bitdefender.com/consumer/support/answer/29358** for full details and a submission form. If it's flagged as clean, the program's virus signatures will be updated, and the file won't be blocked by future scans.

LibreWolf teething problems

I've switched to LibreWolf, as per your recommendation in the December 2024 issue, but despite enabling HTML5 Canvas, some sites that worked fine in Firefox refuse to do so in LibreWolf. These are safe—they're my self-hosted web frontends—so what else I can do to get them working properly?

—James Salazar

THE DOCTOR RESPONDS: This is likely linked to LibreWolf's Resist Fingerprinting (RFP) protection, which breaks some sites. You can verify this by temporarily disabling the feature via Settings > LibreWolf (uncheck Enable ResistFingerprinting) and refreshing the page. If the site works fine and you're happy for it to bypass RFP protections, the good news is that you can disable RFP on a site-by-site basis, but it requires a bit of extra work.

First, type about:config into the address bar, and hit Enter. Type privacy.resistFingerprinting into the 'Search preference name' box to bring up a list of values. Click the Edit button next to privacy.resistFingerprinting.testGranularityMask, and change its value to 4 before clicking the blue confirm button. Double-click privacy.resistFingerprinting.exemptedDomains, and enter any domain or IP address you wish to exclude from the checks (separate multiple entries with a comma). Once you've clicked the blue apply button, the sites should now work correctly again, while other sites remain subject to RFP protections. ⏻

LEAN GREEN FPS MACHINE

Intel's Ultra series has arrived. Is it any good?

INTEL'S IN A BIT of a bind right now, isn't it? Its 14th and 13th gen chips have been rocked by over-volted BIOS and manufacturing failures, leaving it in a somewhat precarious position. In fact, arguably across the industry, this generation of desktop chips has been somewhat cruddy. AMD's processors lack the real punch we'd expect from a gen-to-gen update, with token performance increases of just 10 percent, and on pages 74 and 76, you can read how Intel's Core Ultra series has landed like a lead balloon, with worse single-core performance and paltry power savings, coming complete with hyperthreading removed, and a new nomenclature that makes even the most eager of tech heads scratch their collective craniums.

Is it all so terrible, though? What's it actually like to build with one of these new chips? Well, that's exactly what we wanted to find out with the PC pictured opposite. In short, this build's entire premise stems from creating a testbed that's versatile enough to serve both Intel and AMD moving forward. Picking the right hardware, chassis, cooling, memory, and storage is pivotal to building out a solid testbed like this, and that's something that stays the same, regardless of the chip you're using.

This isn't your typical system, that's for sure. There are odd SSD combos in it, insanely over-the-top motherboards, 64GB of DDR5, and enough cooling and GPU horsepower to make the Steam Hardware Surveys weep with joy. Still, it's also a fantastic opportunity to push the limits of both Intel's latest platform and Geometric's brand new Model 5 chassis. **–ZAK STOREY**

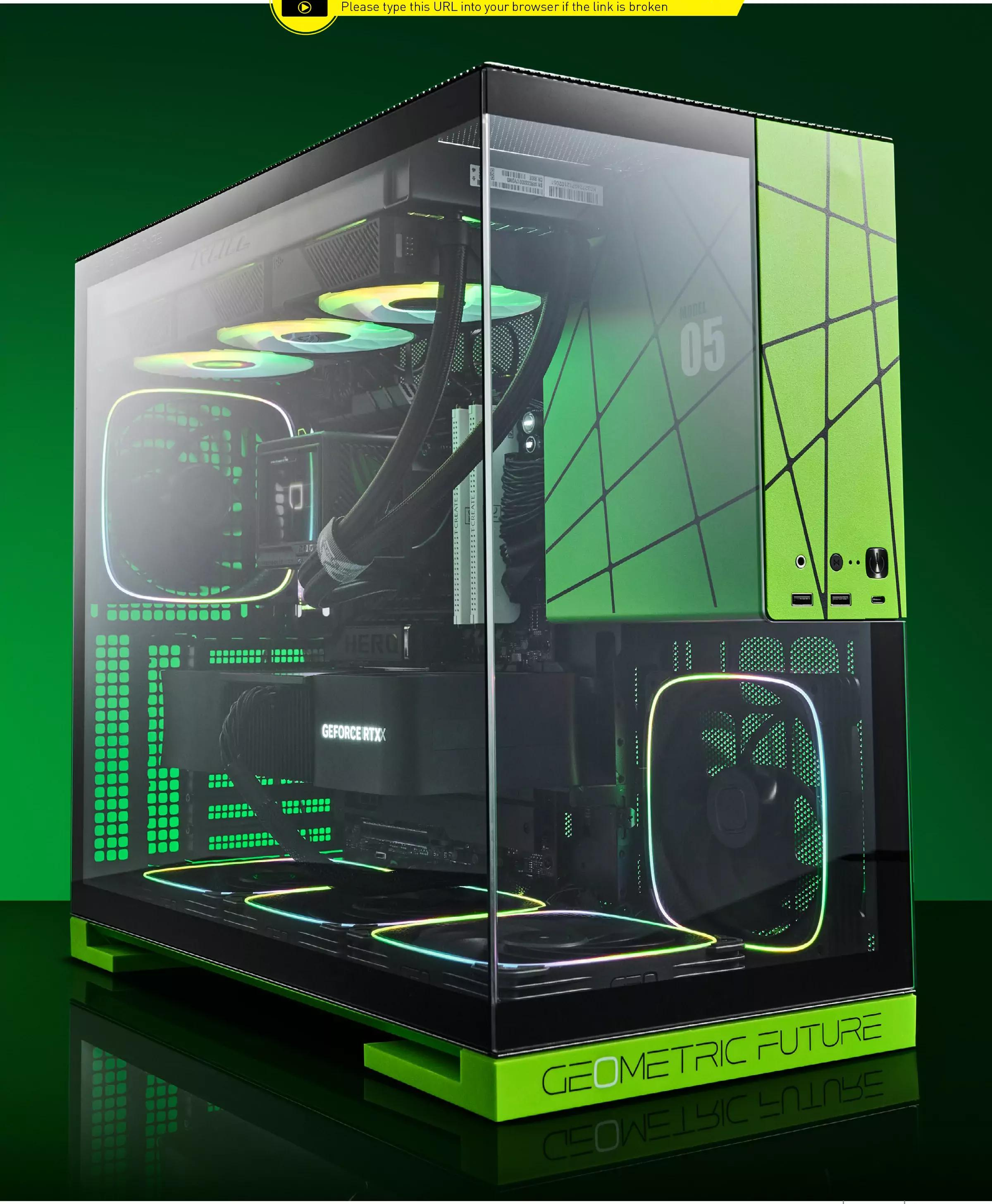
SPECIFICATIONS

Part		Price
CPU	Intel Core Ultra 9 285K	$620
Mobo	Asus ROG Maximus Z890 Hero ATX	$700
CPU Cooler	Asus ROG Ryujin III 360 ARGB Extreme	$480 *(est)*
RAM	64GB (2x32GB) Team Group T-Create Expert DDR5 @ 6000 C34	$160
SSD 1	2TB Crucial T705 M.2 PCIe 5.0 SSD	$295
SSD 2	1TB Samsung 990 Evo Plus M.2 PCIe 4.0 SSD	$90
GPU	Nvidia GeForce RTX 4080 Super Founder's Edition	$1,000
Case	Geometric Future Model 5	$150
PSU	1200W NZXT C1200 80+ Gold	$190
Total Price		**$3,685**
Core Price*		**$2,775**

*"Core Price" refers to the key components generating performance (CPU, GPU Mobo, OS SSD, RAM), not accessories. Asus CPU cooler unreleased in the US at time of writing, pricing based on GBP to USD conversion.

PRICES CORRECT AT THE TIME OF PUBLISHING

https://content.jwplatform.com/videos/4Gk8Vy9s-u2lN49He.mp4
Please type this URL into your browser if the link is broken


MODEL
05
GEFORCE RTX
HERO
GEOMETRIC FUTURE

INTEL CORE ULTRA 9
285K
SRQD5
L434G459

CPU

INTEL CORE ULTRA 9 285K

WWW.INTEL.COM

Here we have it, Intel's latest flagship: the aptly named Core Ultra 9 processor, the 285K. What does the 285 denote? We're not sure. It's got 24 cores: eight performance and 16 efficient cores, and no hyperthreading whatsoever. Maximum turbo frequency tops out at 5.7GHz, and there's 36MB of Intel Smart Cache on board.

TDP is the big one, though; that's been dropped; and maximum turbo power is now 250W, with base power sitting comfortably at 125W. This is the first processor running on TSMC's 3nm manufacturing node, and the first Intel CPU that has deviated from its own fabs in favor of another company's.

The big one, though, is the price. The 285K is available for an outstandingly expensive $620. We'll go into more detail on that later, but it's almost $180 more than the current price of a 14900K. Oh, and it's not backward compatible with previous Z790 motherboards, as it utilizes the new LGA1851 socket. • **$620**

MAXIMUS
HERO

DO IT YOURSELF!
STEP-BY-STEP GUIDE
PG.16

MOTHERBOARD

ASUS ROG MAXIMUS Z890 HERO ATX

WWW.ASUS.COM

Our Z890 testbed motherboard is none other than Asus's ROG Maximus Hero. This thing is a bit of a beast, certainly at $700. It's got support for up to six PCIe M.2 SSDs, three of which can be PCIe 5.0, with a maximum length on the top-most one coming in at the 22110 form factor. DDR5 is supported up to 192GB @ 9,200 MT/s, and that's all backed up by twin EPS 8-pin power, plus an additional 8-pin power directly next to the 24-pin to deliver extra juice to any upcoming future GPUs.

Rear I/O is equally outstanding as well. You get twin Ethernet ports—one at 2.5G, and one at 5G—along with two USB Type C Thunderbolt 4 ports, four USB 4Gbps Type A ports, and five additional USB 10Gbps ports (split between four USB Type A, and one USB Type C). There's WiFi 7, Bluetooth 5.4, a much more simplified audio solution (both gold-plated, one line in, one line out + S/PDIF), HDMI, and Clear CMOS and BIOS Flashback buttons as well. But it sure isn't cheap.
• $700

RAM

64GB (2X32GB) TEAMGROUP T-CREATE EXPERT DDR5 @ 6000 C34

WWW.TEAMGROUP.COM

We've long been advocates of TeamGroup's DDR5 memory solutions, certainly in our Blueprints sections, so it was only right that we got ourselves a decent kit in for our testbed ambitions moving forward as well.

To be clear, Intel sent us a set of 48GB DDR5 @ 7800 MT/s, but given the ridiculously insane costs of those, and the limited performance boost gained from higher frequencies, we opted to go with the TeamGroup kit instead, as it represents far better value for money, looks great, and at C34 @ 6000 MT/s, provides some impressively low latency. Oh, and it's compatible with both XMP and EXPO as well, again allowing us to switch it between AMD and Intel without having to worry. It's perfect on all accounts.

Also, can we take a moment to appreciate that we've got 64GB of DDR5 for well under $200? • **$160**

SSD 1

2TB CRUCIAL T705 M.2 PCIE 5.0 SSD

WWW.CRUCIAL.COM

There was no other choice, certainly not for our operating system drive. Crucial's T705 is a top-tier flagship of a PCIe 5.0 drive, pushing the specification to its limits under the right circumstances. We've used and tested this thing across a number of builds now, and it continues to deliver insane levels of sequential and random 4K performance, all while it keeps itself impressively cool.

If you decide to pick one up for your sequential or OS needs, we recommend making sure you buy one in the right config. If you've got a suitably thick M.2 heatsink on your board, go with the non-heatsinked version. The heatsink variant is great, but if you want to remove the drive from its caddy, you have to pry it out, as there are no screws on this unit like there were on the T700. • $295

CPU COOLER

ASUS ROG RYUJIN III 360 ARGB EXTREME

WWW.ASUS.COM

Asus was kind enough to send us one of its brand new Extreme line of Ryujin coolers. This thing has an absolutely insane price. We don't have any confirmation on what the US RRP is going to list at right now, as it's still making its way over. However, with a bit of quick math and currency conversion, it's looking like it will be nearly $480. That is wild for a CPU cooler.

What we can tell you is that it has ROG Magnetic daisy-chainable RGB fans as standard, capable of driving up to 5.15 mmH2O at full tilt at an incredibly noisy 36 dB (A). There's a fan built into the CPU block itself as well as a pump, and it's got one of the slickest installation methods we've ever seen. Oh, and of course, you get that 3.5-inch LCD display there, too. The best aspect, however, is that it supports LGA1851 and AM5 straight out of the gate, with minimal fiddling when swapping motherboards over. **• $TBC ($480 est)**

SSD 2

1TB SAMSUNG 990 EVO PLUS M.2 PCIE 4.0 SSD

WWW.SAMSUNG.COM

This drive will eventually be replaced by our ever faithful, ever trusty Kingston Fury Renegade in 2TB configuration. But for the time being, we're chucking Samsung's 990 Evo Plus in to see exactly how it ticks.

Samsung's still very late to the party when it comes to PCIe 5.0 drives, and sadly, this still isn't one, but it does sort of feature 5.0 compatibility—well, it supports PCIe 5.0 x2, so that's PCIe 4.0 x4. Don't ask; we don't understand it either. Anyway, compared to the 990 Evo that launched earlier this year, the Evo Plus is utilizing Samsung 236-Layer TLC V-NAND instead of the much more power-hungry and slower 133-Layer TLC in the Evo drive that landed with us just nine months ago. • **$90**

PSU

1200W NZXT C1200 80+ GOLD

WWW.NZXT.COM

With Intel's latest chip power draws falling by the wayside ever so slightly, there's no real need to jump into a bigger PSU—not just yet, anyway. There are rumors of Nvidia's next generation of cards requiring twin 12VHPWR connectors, but we're saving our twin cable 1500W units for a later build.

For now, our tried and true NZXT C1200 ATX 3.1 is more than ample for this build. We did actually try the RMx Shift in this case, but sadly, unlike the Geometric Model 4, it didn't quite fit or give us a categorical advantage. That does mean unsleeved cables once again, mind. • $190

GPU

NVIDIA GEFORCE RTX 4080 SUPER FOUNDER'S EDITION

WWW.NVIDIA.COM

The OG was perhaps mildly underwhelming at the time of its launch, but the RTX 4080 Super is, by modern standards, one of the most proficient GPUs out of the gate. If you're looking for a graphics card that can perform well at 4K or ultrawide resolutions, this is it. It doesn't matter if you're utilizing ray-tracing, DLSS, or AI workloads; it's an absolute beast at whatever you throw at it, and provides far greater value for money than the the titan-esque form of the RTX 4090.

We're starting to see RTX 4080 stock fade into the limelight a little bit these days, so the Super's the card to get; it's slight internal hardware increase is just enough to give it the edge over stock RTX 4080s, but if you're holding onto an overclocked variant, keep holding on; swapping out won't see any performance boosts. • **$1,000**

DO IT YOURSELF!
STEP-BY-STEP GUIDE
PG.22

GEOMETRIC FUTURE
MODEL
05
GEOMETRIC FUTURE

CASE

GEOMETRIC FUTURE MODEL 5

WWWW.GEOMETRICFUTURE.COM

This case (reviewed on page 89) is awesome. For $150, you get such a compact E-ATX tower, it's wild. Okay, there's not a mad amount of support for 3.5-inch drives as such; you won't be turning it into a server any time soon, but the amount of space-saving techniques Geometric has crammed into this thing is outstanding. Simply put, this thing is gorgeous (and fortunately, it doesn't only come in green).

On top of that iconic fishbowl design and flashy green accenting, Geometric also sells this with five included 140mm RGB fans as standard, pre-installed and set up for your convenience. Just be sure to pick up a motherboard with some decent aRGB headers to really take advantage of them. • **$150**

WHY WE ALWAYS PICK TWO SSDs

You might be wondering, "*Maximum PC*, why do you always choose two SSDs for your builds? Surely it's better to get a single drive and partition it?" We're going to cover this in more detail in the next issue when we take you through our ultimate Windows 11 install guide, but we do this for a few reasons.

First, it allows us to simplify our install and file directory processes. The premise is straightforward: install your operating system on your fastest drive. Ideally, you want an SSD with super-quick sequentials and solid random 4K reads and writes, as this is mostly how we're going to be utilizing files.

Our secondary drive is going to be dedicated to games, media, and other programs. In this environment, sequential performance is less important, and random 4K speed is tantamount.

You might be thinking, "Surely a PCIe 5.0 drive is the best pick?" Technically yes, but not always. Some of our highest-rated PCIe 4.0 drives (specifically, the Crucial T500 and Kingston's Fury Renegade) have high Random 4K performance that can often match and even beat top-tier PCIe 5.0 drives in that one field. It's a difficult area to increase performance in.

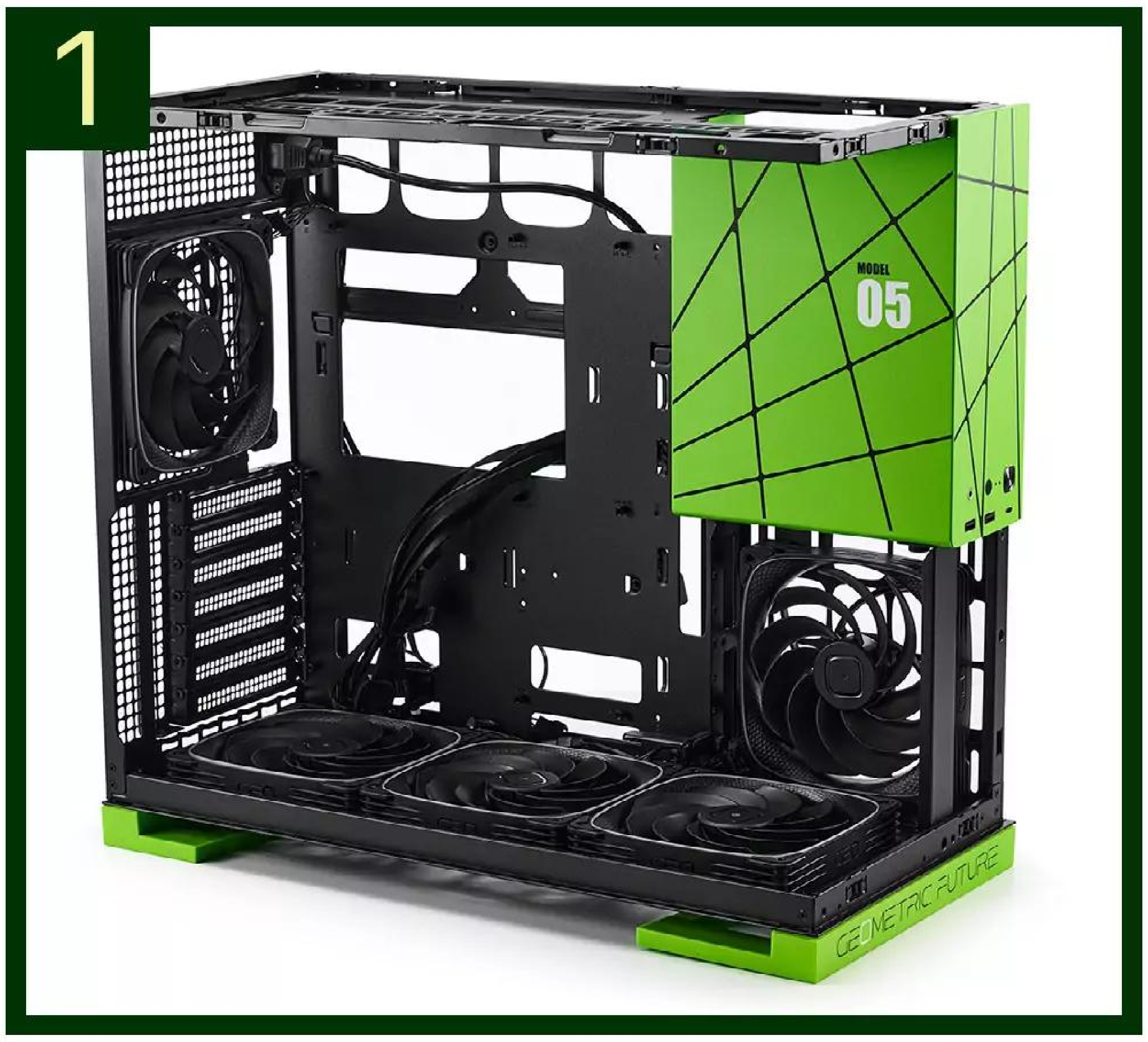
This gives us more wiggle room when it comes to speccing up systems and saving money. You can either grab a 1TB PCIe 5.0 SSD and a 2TB PCIe 4.0 SSD, or 2TB of 5.0 and 2TB of 4.0, instead of 3TB of 5.0 or 4TB of 5.0, and save money in the process.

It also splits the loading; if all your games are on a 5.0 drive with your operating system, that will be under load (even mildly) while it runs background processes and programs. That's going to take up bandwidth and performance, while increasing heat, leading to further bottlenecks if sequential load is high.

Lastly, we're proponents of regularly reinstalling your Windows operating system. We recommend doing it every 3-4 months. It'll clear out conflicting programs, registry entries, and failed driver updates, giving you a smoother running system. If your games and files are stored on a secondary drive, you won't have to re-download them, as Steam, Ubisoft, Origin, and Battlenet can detect them on load-up. That reduces your reinstall time and gives you a pseudo-'off-site' location to store important files you have on your C: drive before reinstalling. Make sure you format the right drive in Windows Installer (when formatting drives, we recommend calling them either their product name or 'games', etc, rather than just 'new volume').

crucial
T500
FURY
RENEGADE

Left: 2TB Crucial T500 M.2 228 SSD.
Right: 2TB Kingston Fury Renegade PCIe 4.0 M.2 SSD.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THE GREEN DEVIL

LENGTH OF TIME: 1-2 hours
DIFFICULTY: Easy

AH, a return to normality—sort of, anyway. This might be a new generation of Intel processors, with odd naming schemes and curious performance, but as far as the build process is concerned, very little has changed. It's all down to the chassis at hand. That's the real trick with these builds—no matter how you look at it, throughout custom PC building history (it's a thing, we promise you), it's the case that dictates all. It tells you what you can install, in what order, how best to route the cables, how to maximize the cooling potential you have, and what hardware to install without thermally throttling. So much of it is reliant on that big old box.

It's why Geometric's chassis are so interesting, certainly to this journalist. It's because of that very element at their core. They're different. They're unique. They make you think outside the box, radically alter your build order, and try new things to see what fits and what doesn't. It's a challenge, but in a good way. That's perhaps something that's unique to those of us who regularly build a great number of these machines; perhaps you just want a simple, straightforward system build, and yeah, the build order on this thing is wildly different, but as long as you approach it with a sensible attitude, give it some time and patience, and follow a good guide, you'll end up in a very similar place, with a build that looks just as exemplary, if not better.

RE-ORDER THE BUILD ORDER

So then, the first thing we're going to do, like with all of our *Maximum PC* builds, is strip down the chassis to as few parts as we can. We do this for two reasons: to protect those large glass and metal panels that this thing is littered with, and to minimize clutter and ensure we have the maximum amount of cable management space possible (it's also handy, as it gives us a bit more room to maneuver internally, and the chassis becomes a lot easier to move about on our workspace). The Model 5 is fairly easy to disassemble on the whole. The windows, roof, and rear panel are all entirely toolless, held in by pop studs and clips, and that's it. There's a dust filter underneath those three bottom fans, and a funky 'display mount' that's attached to the PSU shroud as well (for displaying tiny miniatures on, genuinely) **(Step 1)**.

What we have left in place, however, are those five fans. They're included with the case as standard at this price point, have RGB rings integrated into them by default, are nicely cable managed into position, and you might notice that those bottom ones are actually reverse blade designs as well. So the bottom four 140mms are acting as intakes **(Step 3)**, and the topmost fan is acting as an exhaust, but there's not a single fan guard in sight. Nice. They're all daisy-chainable as well, and all operate off a single aRGB header for lighting and a PWM header for fan control. All good stuff.

Interestingly, we've decided to go a bit left field with this build, certainly when it comes to our build order. Because this tiny box here **(Step 2)** is going to be a bit of a nightmare to cable manage around, if

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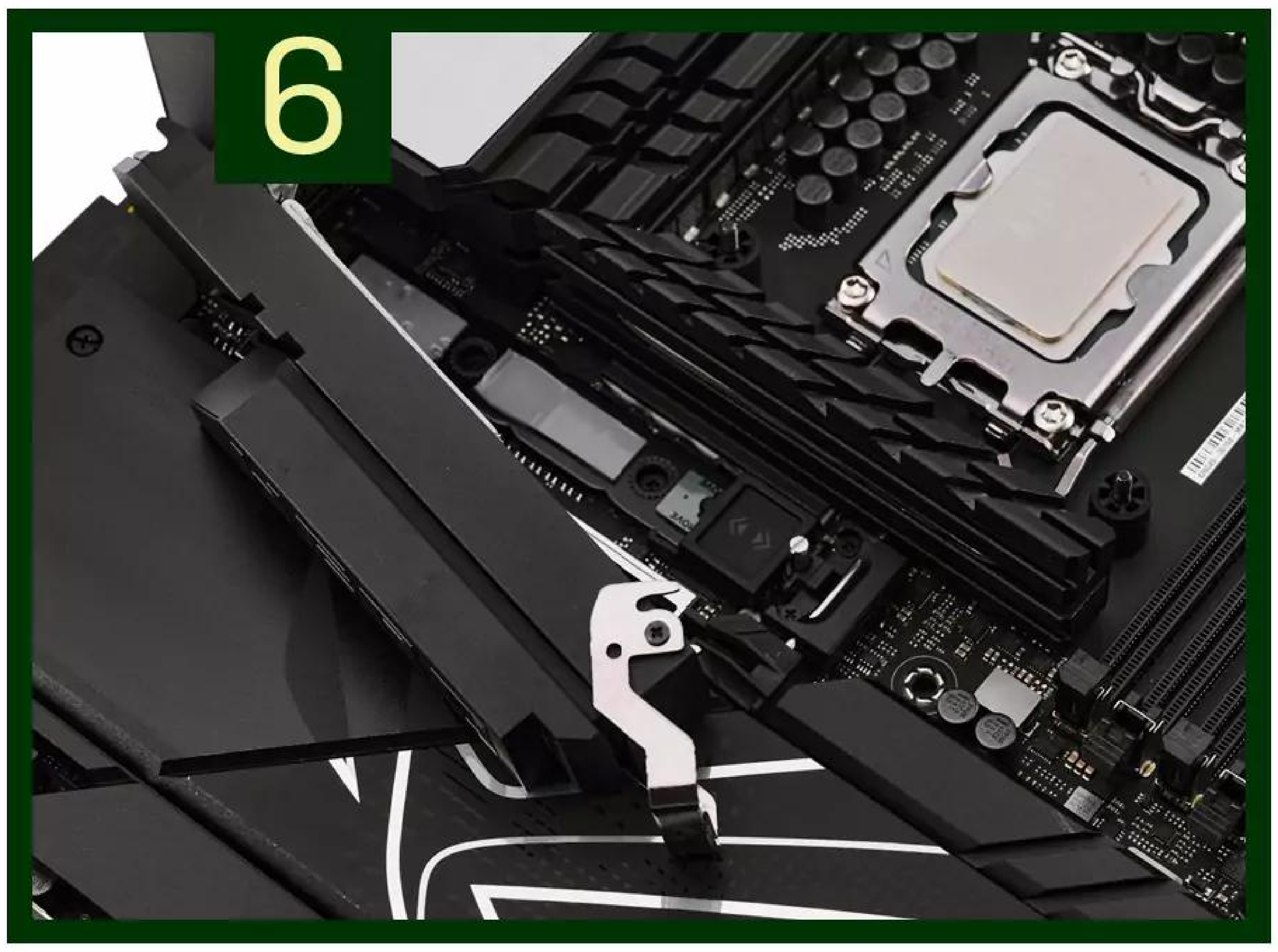

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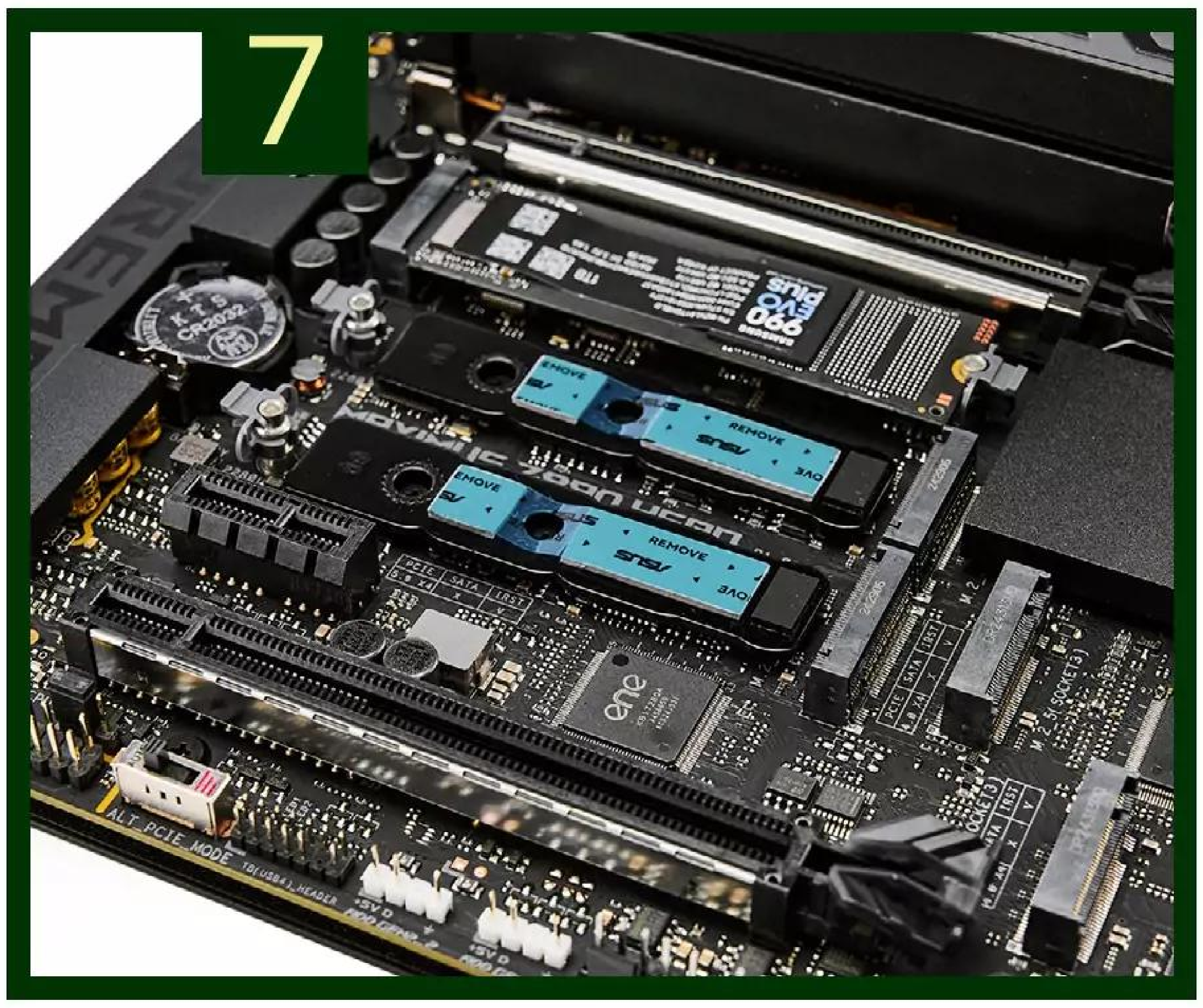

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we leave it until last, it's best to try and get the PSU in now. You'll also notice that all the front I/O is trailing through that cable management hole as well. Now, initially we did give the Corsair RMx Shift a go in here, just to see if it'd fit, but remarkably, it's actually too long. There's just no way of getting it to fit without crushing or conflicting with those bottom I/O cables, sadly. The Shift is naturally longer because it's having to accommodate all the hardware necessary to deal with those shifted smaller PSU connectors (ironically). Instead, going with a 1200W NZXT unit gives us a bit more wiggle room and a far simpler design as a result.

CABLE ROUTING

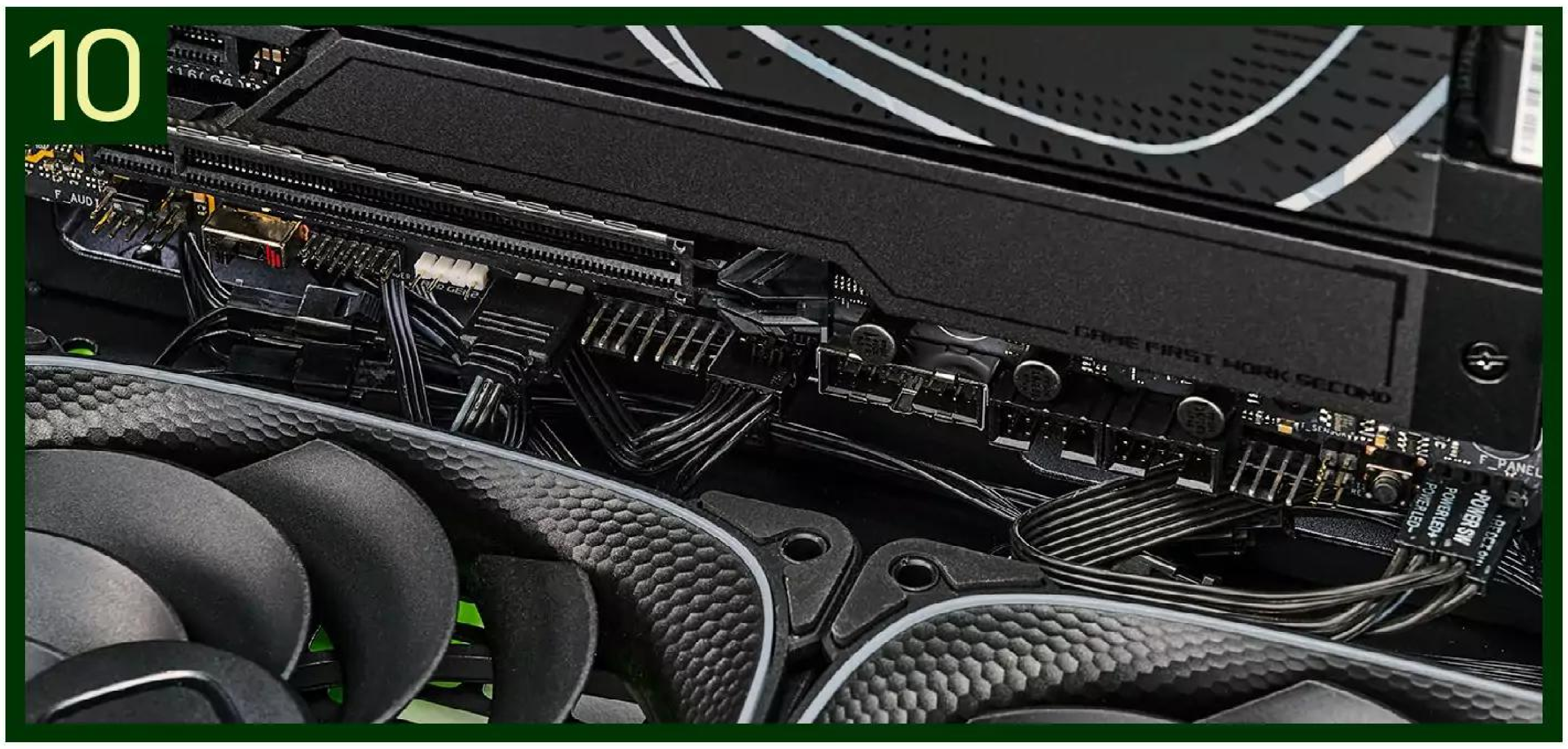
To install the power supply, there's a bracket at the top of the PSU cover area that's secured with a single screw and slides into position. Attach the PSU to that, then the cables you need, slot it into place, slide and re-secure, and you'll be good to go. We've also taken the opportunity to route the PSU passthrough cable up here as well, weaving it around the back of the case. Geometric initially runs this along the top of the motherboard tray. That's because it's actually provided mounts in the rear of the motherboard to add an additional two 120mm fans behind the motherboard directly. If we're honest, we're not entirely sure how adding an extra exhaust or intake here would help (we'd have to see the science/testing behind it), so with that in mind, we've gone ahead and ran the power lead passthrough where those fans would be **(Step 4)**. You can also see we've pre-routed all of our cables out and around the back as well to deal with later. This does make it a little more awkward to install the motherboard, as you have to make sure you're not crunching your cables accidentally on the edges of the case, but it's a small price to pay for an easier PSU install later.

Onto the motherboard prep, and we get our first look at the shiny Core Ultra 9 285K chip **(Step 5)** in all of its glory. There's not a lot to report on here—once you've installed one LGA chip, you've installed them all. Move and lift the retention arm up and to the right. Lift the CPU bracket up and out of the way, then carefully lower your CPU into the exposed socket, making sure to align the golden triangles and the notches in the chip with the notches on the board. Failing that, you can also tell by the writing on the chip itself. Then, lower the retention bracket back down (leaving the plastic cover on), re-latch the retention arm, and the plastic bracket will pop off, and you're done.

We've also gone ahead and installed the Asus Ryujin Extreme's mounting bracket solution to the board as well. It's amazingly simple to do, this one. Grab the Intel bracket, thread it through the holes in the back of the motherboard, then secure in place with the correct plastic spacers. That's it. They grip the threads, and you're good to go.

STORAGE, SO MUCH STORAGE

With our CPU in check, it's time to move onto getting that Crucial T705 in. We've already carefully pried it out of its included heatsink (please just buy the heatsinkless version and slap it in your mobo's heatsink—don't do what we had to do). Then, we've got to remove the heatsink from the board itself. Asus has done an awesome job with the design on this—it's got a huge metal latch. Lower that down, slide the heatsink off,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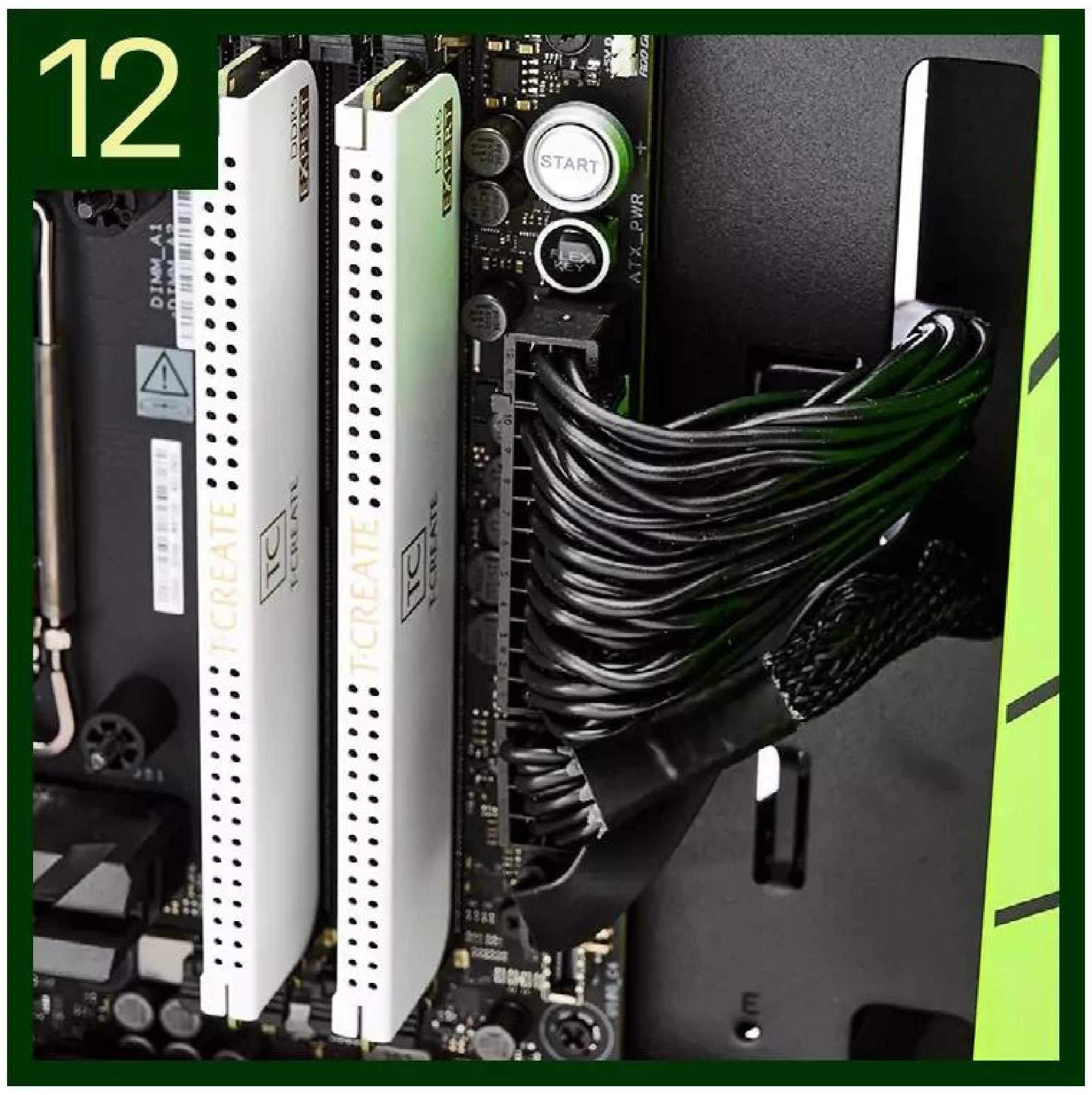
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and you'll reveal the PCIe 5.0 M.2 slot underneath (Step 6). Asus has included thermal pads on both sides; remove the plastic film from those, then place your M.2 SSD into the connector, push it into place, slide the Q-latch into position, and it'll secure the drive. Then, replace the big heatsink, latch it back in place, and you're cruising.

Sadly for any other SSDs, you're going to have to remove the entirety of that bottom plate to gain access to them (Step 7). It's not as seamless as what you'll find with the X870E-E Strix Gaming WiFi with its multiple heatsink designs, but realistically, you shouldn't be swapping out your M.2s, anyway. Remove the four Philips head screws from each corner, and you'll reveal the M.2 slots underneath. The topmost one is PCIe 5.0 (where we'll be installing our 990 Evo Plus), and the other four are our PCIe 4.0 solutions ,if we ever need them. Remember to remove the film covering the thermal pads on the other slots if you do intend to use them. There's film both on the mounting location and the back of the heatsink.

(Step 8) We know what you're thinking; here he goes, telling us how to install RAM again. Not quite (although if you need to, lift the latch up on either end, line the notches up, and slide the DDR into position, making sure to use every other slot). Interestingly, this shot actually highlights two things we need to talk about, and it's all to do with ports. Those two USB C headers, for a start; that bottom left one is rated for 10Gbps, and the most right one is rated for 20Gbps, so if you've got a singular USB C port on the front of your rig like we do, ensure that you're using that topmost one.

Secondly, you might have noticed that additional PCIe power to the left of the 24-pin. This isn't the first time we've seen this happen; a number of older Z790s and their predecessor boards had them as well. Effectively, it allows the mobo to deliver more power to PCB components—PWM fan headers, for example, along with driving extra voltage to the PCIe lanes.

What's more annoying, however, is that in the older boards, you could actually forgo plugging this PCIe power in, certainly in the Z790 Dark Hero. Not the case on the Z890. If you do install PCIe power here, you'll end up in a continual boot loop, not making it past BIOS. Fun.

THIS IS WHERE THE FUN BEGINS

With our board prepped, it's now time to get it in the chassis. Flip the case on its side (making sure not to crush the cables from earlier), and carefully position the motherboard over the stand-offs. Use the included screws that came with the chassis (Step 9), then secure it into position. Now, it's time to start thinking about cooling and cable management.

The only problem with leaving those fans in from earlier and not removing them from the chassis is that you have to deal with problems like this (Step 10), namely struggling to plug in all of the cables we need down here. We've got a cable for the RGB on the fans, the fan cable itself, along with all of the pins for the front I/O, and we have to navigate all those daisy chained cables running around the bottom, too. It's a bit of a nightmare, to be completely honest, and just goes to show how sometimes, removing everything is a better choice.

Next up, we grabbed the CPU power cables and slotted them into position (Step 11). Curiously, this is where those two 120mm fans can technically be mounted behind the motherboard tray, 15

16

17

but this is just a far better use case for that space and makes the whole process so much easier. Lastly, the 24-pin, plus its corresponding PCIe power, as well as the top most USB C cable is in position, too **(Step 12)**. Geometric's got a bit of a habit of running these slim-line USB C cables in its rigs, making them super easy to route.

On to the CPU cooler, and this thing is a beast. We installed the radiator into the top of the chassis, then placed the CPU block in position. The Ryujin comes with an Intel bracket pre-attached. We removed the LCD display off of the block itself, revealing the small fan underneath, as it gave us better access to the screws on either side.

Interestingly, although the display itself is magnetic, it can only be placed on the centre block in one particular orientation. Those contacts in the top-right **(Step 14)** cannot be moved or re-oriented, and touch contacts in the LCD display itself is rather frustrating. This thing is big, too—seriously big. Noctua's CPU cooler from last issue's ITX build is lower than this thing. Asus has also pre-applied a good helping of thermal paste to the cooler; we've gone ahead and removed that so we can add our own Noctua NT-H1 paste to the mix instead (the same old rules apply: small dollop in the middle of the chip), and that's it. Then it's onto the fans.

Asus has gone with quite the unique daisy-chaining system. It's utilizing magnets and contacts in between the three fans to allow RGB data, fan speed, and power to traverse the lot of them, and then on either end you can attach a single male or female magnetic power cable **(Step 13)**. This similarly snaps into position, and also has its own orientation that needs to be adhered to. We did have a touch of trouble with the contacts not quite lining up on a few occasions, causing the second and third fans in the chain to not spin. A quick tightening of the screws fixed the issue, however.

With our CPU block and fans secured, we replaced the LCD screen back on top, also magnetic **(Step 15)**, then ran the cables for both the pump and the display up past the memory, and out into the back of the chassis. The display operates off a USB header, and needs routing again down to the bottom of the chassis.

GRAPHICS SHENANIGANS

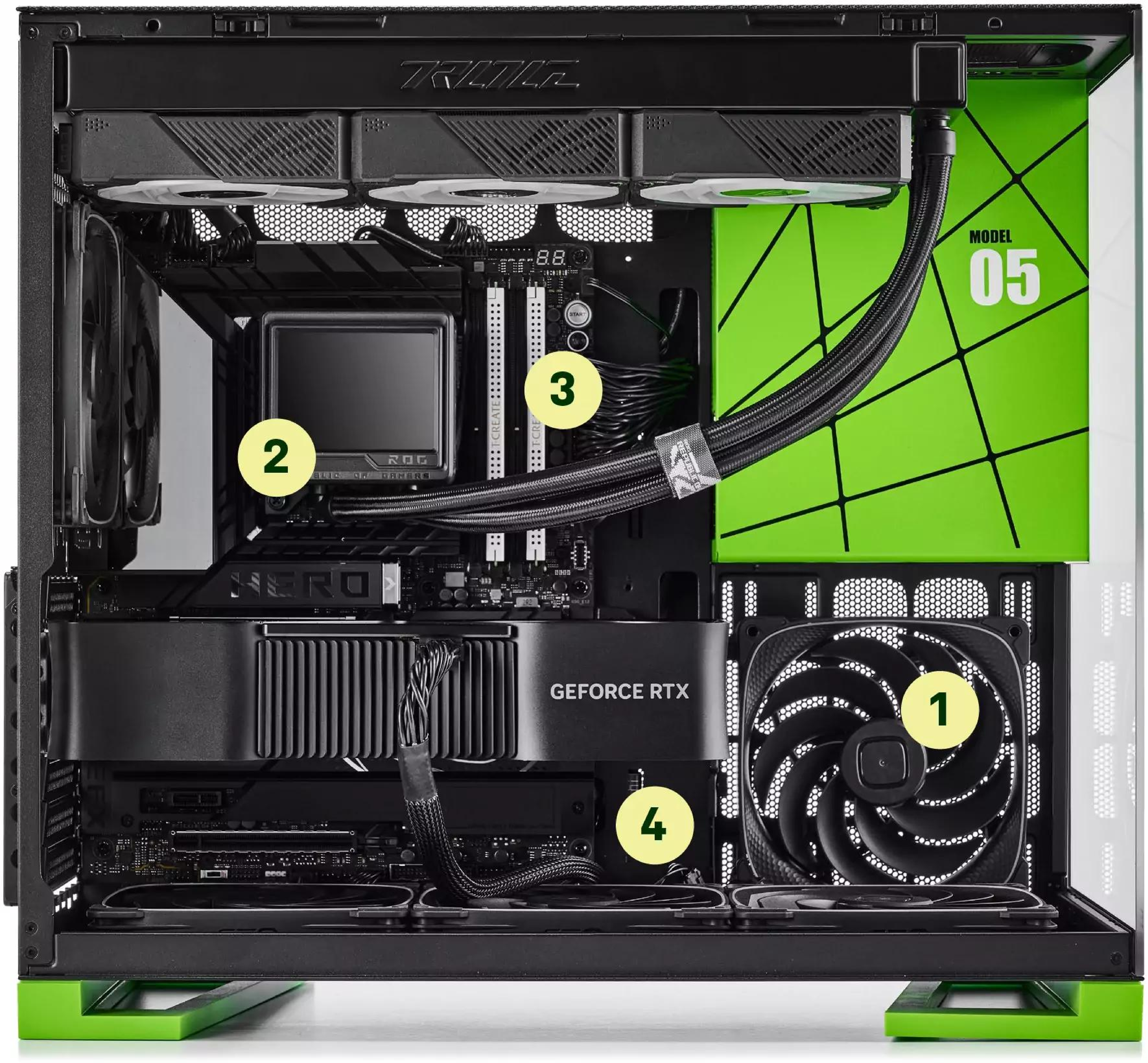
With that, it's time for the final piece of the puzzle: our RTX 4080 Super. This took us a while to figure out; we struggled a touch, but for one bizarre reason: unfortunately, we didn't have a small enough screwdriver to secure the GPU into the case after removing the PCIe slot covers. Interestingly, Geometric actually enables you to remove the entire PCIe slot. This is to allow for vertical GPU mounts; however, rather foolishly, we attempted to pre-attach the GPU to this unit outside the case, **(Step 16)** then re-install it back into the case. Unfortunately, there's no way of doing this, as weirdly, you have to slot it into the PCIe slot on the motherboard, while simultaneously sliding the entire PCIe slot unit back into the case, and sadly, the clearances don't allow for it.

A quick trip to a local hardware store, and we were sorted **(Step 17)**. With the GPU in place, we then adjusted the integrated GPU sag support bracket (you can just about spot it on the bottom right of that image) that comes included with the case, then installed the 12VHPWR cable, and we were all set.

POLYGONS ALL THE WAY DOWN

THIS BUILD, if we're honest, is outstanding. It's been with us now for over two weeks, and it's just a thing of beauty. We didn't quite have the time to get Asus's Armory Crate installed on the day, and as such, couldn't configure the internal lighting, but with it all set to a lovely shade of green, it just absolutely pops (seriously, we tried to get it done on the day, but it took 45 minutes to install over a hotspot, and still hadn't finished by the time the shoot wrapped).

In short, it looks stellar. Fishbowl cases have become increasingly popular over the last few years, and you can see why; those twin glass panels give you an unprecedented view of the hardware within. If you've got the gear to show off, then it's almost a must. On top of that, temperature and air intake have been handled to perfection, too. Geometric has been pretty strict on its case design over the last few models we've tried; almost all of them feature that chimney design, three intakes in the floor, and exhaust straight up out of the roof, working with convection, rather than against it. That seriously pays dividends, and we've not seen any major cooling problems during testing, either.



1 This side fan might seem quite small for the space. It's 140mm, but the chassis intriguingly can handle 160mm fans as well. This is the first we've heard of that form factor, if we're honest.

2 Asus's Ryujin CPU block is absolutely massive. It's got an integrated fan (we're still not quite sure how that helps), but the display is a beauty, and looks stunning.

3 Intel actually shipped its testbed press kit with a set of 48GB Corsair Dominator Titanium @ 7800 MT/s, but we've forgone that for 64GB of TeamGroup instead because, y'know, more RAM.

4 To the bottom right of the GPU, you should just about be able to spot the integrated anti-sag bracket. It's tiny, built into the case, and honestly a masterstroke.

Overall, the build process was fairly standard. There are a few caveats to that, namely finding a power supply that would fit, but all in all, it was quick, direct, and straightforward to put together. There was a bit of fiddling with the cables here and there, but given the quality of those internal fans, we didn't need to swap them out, and since there's five of them included straight out of the box, there's no need to add extras, either.

What would we change? Cables, of course. Opting for something with a bit more sleeved flair is something we aspire to with these builds. Aside from that, genuinely opting for a different cooler would also have been a smarter move. Don't get us wrong—a 360mm AIO is a nice thing to have (and one we'd highly recommend for either Intel or AMD's latest chips), but paying close to $500 for a cooler is a bit ridiculous. That's RTX 4070 Super money on the low side, which makes us feel a little bit uncomfortable, and if we're honest, we're not entirely sure why. Okay, you get a decent LCD screen and some magnetic fans, but little else. Also, that CPU block is very tall. We'd wager that it's close to Noctua NH-U12S height, and given one of the defining positives of an AIO is the smaller CPU block compared to an air tower, this feels like a little bit of a misstep.

Still, it's a fantastic build. With a few tweaks, it'd be close to perfect. Oh, and don't worry, we'll be removing that 990 Evo Plus out of here pronto in the next few days, and getting our ever-reliable Kingston Fury Renegade back instead.

INTEL'S LATEST GENERATION

HOW WE TEST

Each month at *Maximum PC*, after our builds are completed, they go through a massive, rigorous testing suite of benchmarks and workloads designed to push them to the absolute limit of what they can possibly achieve. It's imperative that we do this, as it gives us an insight into just how well these systems hold up in specific tasks, and hopefully indicates how they'll perform, not only in day-to-day operation, but also in more specialized workloads.

We cover everything from 1080p and 4K gaming to CPU benchmarking performance, along with SSD tests, and also run each system through an arsenal of synthetic and AI performance benchmarks. This gives us a huge amount of data to look at, and provides us with an archive of snapshot data from when those systems were tested. Each and every test we perform here at *Maximum PC* is run three times to calculate the average results. In scenarios where one result looks wildly out, we'll repeat the test as many times as necessary to get consistent results, or try to identify what might be causing the issue, and remedy it accordingly.

THIS ISSUE'S ZERO POINT

This issue's Zero Point is a bit of a special one, as it's a direct apples-for-apples comparison. As this is Intel's latest-generation flagship, we wanted to challenge it directly against the 14900K from the last gen. However, we've actually got two sets of results for that system: one based on the BIOS microcode prior to the stability fixes, and one after. For all of our graphs, we'll be utilizing the more modern micro-code variant, as this is the one that consumers can expect to find in today's world (and systems we'd highly recommend updating the BIOS to, if you haven't already). It's also worth mentioning that the GPU is different between these two rigs as well; the 14900K machine is taking advantage of Gigabyte's RTX 4080 Aero OC, and our Core Ultra 9 285K build has the RTX 4080 Super from Nvidia. In our testing, both of these graphics cards score around the same: within 1-2% of each other in benchmark results.

All in all, our zero point features the Intel Core i9-14900K, Z790 Asus ROG Dark Hero motherboard, a 360mm Phanteks Glacier One 360D30 AIO, 32GB of Lexar Thor OC DDR5 @ 6000 C32, a 2TB Crucial T700 PCIe 5.0 M.2 SSD, a 2TB Kingston Fury Renegade M.2 PCIe 4.0 SSD, and an RTX 4080 Gigabtye Aero OC GPU, all packed into Geometric Future's Model 4 Caliburn, and powered by Corsair's 1200W RMx Shift PSU. That's backed up by one triple pack of Phantek's M25-120 fans.

The total price for the zero-point build at the time of writing is $3,485 (5.74 percent lower), with a core price of $2,677 (3.66 percent lower) than our Lean Mean FPS Machine.

CORE ULTRA 9 285K VS CORE I9-14900K

This really was the battle to end all battles. Don't worry, we'll get to AMD versus Intel in a future build, but it's safe to say that the jump between these two chips is, well, challenging to justify, to say the least. Intel has radically altered the overall chip design on the Core Ultra series. Long gone are hyperthreading and other power-heavy operations, and similarly, this is the first time we're seeing TSMC cores with Intel's architecture make their way to the stage. Honestly, we're not entirely comfortable with that, but nonetheless, fabs are ridiculously expensive to build, and so that's perhaps not surprising, particularly as we get down into the sub-3nm range.

This generation is all about power savings above all else, and that has clearly reared its head. A quick glance at the power draw charts, and you'll see that the maximum power draw during testing has radically dropped from the 14th-gen build to the Core Ultra line, going from 618.2W down to 535.9W. Considering that had already decreased thanks to those micro-code tweaks, falling from 694.9W under load, and well, that's a radical decrease, that's for sure.

Temperatures sadly haven't followed suit, although perhaps we should be thankful the Core Ultra 'only' topped out at 97.5 C, instead of a constant 100 C, like its predecessors.

The real curiosities lie in the world of performance. In traditional benchmarks—Cinebench 2024 in particular—the Core Ultra performs admirably, certainly in the multi-core tests, delivering 2,252 points in Cinebench. This is impressive, given that it's only got 24 threads versus the 32 in the 14900K (scoring 1,923). What's not so fun is the drop in single-core performance. The Core Ultra landed just 98 points in that domain, versus the 125 of the 14900K. Geekbench reports similar as well, with single core landing at 2,072—a whopping fall from grace of the near 3K points that the 14900K managed. Equally, Geekbench also marked the Core Ultra down in multi-core, falling under par for that particular test compared to the 14900K (which we'd like to point out is currently selling for $180 less).

THE WORLD OF GAMING

Intel's been working hard to rectify its gaming performance since launch, and we're starting to see that get through, although only ever so slightly. On

GEOMETRIC FUTURE
GEFORCE RTX
05

the whole, we're getting some really fascinating results, with a lot of outliers. At 1080p, *Cyberpunk 2077* was mostly on par between generations, with both chips scoring around the 86 fps mark without upscaling and 202 points with it. *Final Fantasy XIV* also saw very similar frame rates around the 210 mark for both chips. *Far Cry 6*, an AMD-sponsored and older title, however, saw a massive drop of near 15fps compared to the 14900K, scoring just 156 points to 171. What's curious about that 156 score is that the frames were almost always wildly different, ranging from 151 at its lowest run to 163 on its highest, but always fluctuating wildly in between. Then there's *Total War: Warhammer 3*, an Intel-sponsored title, where the Core Ultra managed 210fps on average, absolutely demolishing the 14900K's 161 (it in turn fell foul in the stability BIOS updates, falling by 10fps from 173). It's perhaps unsurprising that optimizations were seen there, given how popular the game still is, and how prominent an Intel title it was as well.

4K results saw an uptick as well, this time across the board, with higher results in both of our *Cyberpunk* tests, *Total War* and *Final Fantasy*, respectively. We suspect these results might be down to how Windows is allocating threads to applications, and the fact that Intel now has each core only managing a single thread, which might be more beneficial at 4K than with its previous generations, thus the upticks. This gives it a categorical edge in 4K gaming, even compared to Intel's previous gen with the old microcode.

SYNTHETIC AI

Heading over to the realms of 3D Mark and UL Procyon, and there's some interesting data to digest here as well. Scores across Speedway and Steel Nomad swung in Intel's favor, with numbers comfortably higher than both Intel 14900K variants. Night Raid, our more floor-leveling mobile title, however, flattened that uptick somewhat with a far lower overall score, and again, CPU Profile did boost up considerably, flattening the 14900K with an additional 2K on the score.

Then we get to the AI side of things, and oh boy, is it a mess. Good news first: it does have an NPU on board, and that boosts inference performance. In fact, it landed a score of 70 in Computer Vision using Windows' Machine Learning API, and average inference time has massively improved, falling from 659.88ms to 465.53ms gen on gen. On ML GPU, on the other hand, performance fell through the floor, with 1,161 points versus 1,902 for the 14900K build, and sadly, TensorRT couldn't save it either, with the Core Ultra scoring just 1,938 versus the 14900K's 2,532. We also have to consider that the 14900K machine has the older RTX 4080 Aero OC, which has less internal hardware than the RTX 4080 Super does, and that was all backed up with poorer results on the average inference time on all tests.

Image generation, on the other hand, was wildly different between the two machines, again with the Core Ultra series blowing past the last generation, scoring 4,069 to the 14900K's 3,389 with TensorRT, or 3,002 to 2,616 with ONNX.

PLATFORM TEETHING ISSUES

Here's the thing—really, this is Intel finding its feet on a new architecture design. It just came at the worst possible time for the company. In archery, there's the idea that just one variable can change, and your entire shot process will go awry. You'll start missing, slinging arrows left and right. You then start changing everything in a panic, and it becomes predominantly worse very quickly until someone says, "Look, you're doing X, Y, and Z wrong; fix it," and then all of a sudden, you're better than you were before.

With Intel, it feels like it's exactly that. It's a new chip architecture, it has an integrated NPU, there's no multi-threading, clock speeds are lower, power draw is more efficient, TSMC's handling the manufacturing process, and Windows doesn't quite know how best to manage the resources it has. Plus, it's all come at a time when AMD's launched a new generation of processors that although not exciting, perform slightly better than before. Combine that with Intel having had so many issues with its last two generations of processors, and well, it's problematic. So many elements come together to deliver the worst possible outcome at the worst possible time. Pile on stockholder woes, and the headlines aren't going to look too stellar for the company in the upcoming months.

Intel's now working on system fixes and patches and pushing new microcode to improve performance, but that means we're left with processors that, ironically, will perform worse on the first launch than in six months time—the exact opposite of what we saw with the 14th gen.

This isn't the death knell for Intel, not by a long shot. It's not too big to fail, but as a company, its investments and R&D are incredibly diverse and well thought-out, but it does mean that right now, it's perhaps not the best it could be. This feels like it was meant to be its Ryzen moment, and it still could be, but for now, it feels a little undercooked.

SYSTEM BENCHMARKS

For our system testing, we use a multitude of separate benchmarks. For our CPU tests, these include Cinebench 2024 and Geekbench 6.3.0. All results are indexes in this case. Multicore per thread is achieved by dividing the total multicore scores by the number of threads on the CPU. For storage testing, we're taking advantage of CrystalDiskMark 8.0.5—the best scores are in bold, and all results are reported in MB/s. Throughout our entire benchmarking process, we test each system with a power meter plug running, and the latest version of HWMonitor installed and up as well. This allows us to report on the maximum power draw and temperatures seen over the entire benchmarking process.

CPU PERFORMANCE CINEBENCH 2024 & GEEKBENCH

	ZERO-POINT	
Cinebench 2024 Multi-Core	1,923	2,252 (17.1%)
Cinebench 2024 Multi-Core Per Thread	60	94 (56.7%)
Cinebench 2024 Single-Core	125	98 (-21.6%)
Geekbench 6 Multi-Core	20,016	19,931 (-0.42%)
Geekbench 6 Multi-Core Per Thread	625.50	830 (32.7%)
Geekbench 6 Single-Core	2,997	2,072 (-30.9%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

STORAGE PERFORMANCE CRYSTALDISKMARK 8.0.5

	ZERO-POINT	
C: Sequential Read/Write Q8	11,823/11,275	**12,415/12,456**
C: Random 4K Read/Write Q1	63.04/301.83	**83.59/317.86**
D: Sequential Read/Write Q8	6,839/**6,659**	**7,037**/6,165
D: Random 4K Read/Write Q1	**89.38/329.38**	78.64/298.67

POWER DRAW & TEMPERATURE HWMONITOR & DEDICATED POWER METER

	ZERO-POINT	
Max CPU Temperature	100.0 C	97.5 C (2.5%)
Max GPU Temperature	72.0 C	67.0 C (6.9%)
Max System Power Draw	618.2 W	535.9 W (13.3%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

GAMING BENCHMARKS

Game tests are performed on Ray Tracing Ultra *(Cyberpunk)*, Ultra *(Far Cry 6)*, Maximum *(Final Fantasy: XIV Dawntrail)*, and Ultra *(Total War: Warhammer 3)* graphics presets. Three runs are performed per title, per resolution. *Cyberpunk* is always tested with ray tracing enabled regardless. Under its second set of conditions, DLSS/FSR/XeSS is enabled in *Cyberpunk* dependent on GPU manufacturer, with upscaling preset set Quality. Nvidia cards also have AI Frame Generation enabled. *FF XIV: Dawntrail* is utilizing FSR across the board regardless of GPU, with LOD on Distant Objects enabled, and dynamic resolution disabled. *Far Cry 6* is tested with DXR disabled, and the HD Texture pack downloaded and enabled.

1080P PERFORMANCE

	ZERO-POINT	
Cyberpunk 2077 Stock (Avg/Min FPS)	85.2/68.9	**86.3/72.9**
Cyberpunk 2077 AI Upscaling (Avg/Min FPS)	**202.4**/157.9	202.3/**163.3**
Far Cry 6 (Avg/Min FPS)	**171.3/134.0**	156.3/118.0
Final Fantasy XIV: Dawntrail (Avg/Min FPS)	208.5/**89.0**	**211.5**/82.7
Total War: Warhammer 3 (Avg/Min FPS)	161.4/111.7	**209.8/168.0**

1080P PERFORMANCE

	ZERO-POINT	
1080p Titles Aggregate (Average FPS)	165.77	173.23 (4.5%)
1080p Titles Aggregate (Minimum FPS)	112.30	120.98 (7.7%)
		0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

4K PERFORMANCE

	ZERO-POINT	
Cyberpunk 2077 Stock (Avg/Min FPS)	26.7/17.6	**30.6/627.1**
Cyberpunk 2077 AI Upscaling (Avg/Min FPS)	75.7/39.2	**87.0/79.4**
Far Cry 6 (Avg/Min FPS)	108.3/76.7	**109.7/498.3**
Final Fantasy XIV: Dawntrail (Avg/Min FPS)	94.6/57.3	**100.2/62.7**
Total War: Warhammer 3 (Avg/Min FPS)	66.8/50.7	**75.5/57.0**

4K PERFORMANCE

	ZERO-POINT	
4K Titles Aggregate (Average FPS)	74.42	80.57 (8.3%)
4K Titles Aggregate (Minimum FPS)	48.30	64.90 (34.4%)
		0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

SYNTHETIC GAMING BENCHMARKS

We're using 3DMark's latest Speed Way, Steel Nomad, Night Raid, and CPU Profile tests. Speed Way represents a DX12 title at 1440p, with ray-tracing elements, Steel Nomad is DX12 4K without ray tracing, and Night Raid (DX12) is designed with integrated GPUs in mind at 1080p. CPU Profile acts as an additional CPU benchmark (reporting on max thread output only), with specific gaming workloads prioritized. Each synthetic test is run three times, and indexes are reported on.

3DMARK PERFORMANCE

	ZERO-POINT	
Speed Way (DX12 + RTX @ 1440p)	7,246	7,327 (1.1%)
Steel Nomad (DX12 @ 4K)	6,541	6,629 (1.3%)
Night Raid (DX12 @ 1080p)	95,238	86,718 (-8.9%)
CPU Profile	15,312	17,547 (14.6%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

AI INFERENCE BENCHMARKS

For our AI testing, we use UL Procyon's Professional Benchmark Suite. We focus on its AI Computer Vision (which gives us a gauge on how our systems operate when dealing with inference engine tasks), and AI Image Generation benchmarks. For Computer Vision, we report on the total inferences performed, the average inference time, plus the Index score across all tests. The Index score is more valuable, as it's the time taken between inferences that indicates performance. We run all tests on AI Vision using Float16 precision. We test both the CPU and the GPU under Microsoft's ML API.

For Image Generation, we test under Stable Diffusion 1.5 (Float16 precision), using all engines available. However for comparison, we only include scores from the same engine. We report on the Index score, the time taken, and the image generation speed. All results are averaged across all tests. Best scores, where appropriate, are in bold.

AI COMPUTER VISION PERFORMANCE

	ZERO-POINT	
Microsoft ML API CPU (Index)	50	70 (40.0%)
Microsoft ML API GPU (Index)	1,902	1,161 (-39.0%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

	ZERO-POINT	
Microsoft ML API CPU (Total Inferences)	10,284	13,666
Microsoft ML API CPU (Average Inference Time)	659.88 ms	**465.53 ms**
Microsoft ML API GPU (Total Inferences)	226,692	132,232
Microsoft ML API GPU (Average Inference Time)	**9.883 ms**	14.29 ms

AI IMAGE GENERATION PERFORMANCE

	ZERO-POINT	
Stable Diffusion 1.5 ONNX (Index)	2,616	3,002 (14.8%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

	ZERO-POINT	
Stable Diffusion 1.5 ONNX (Time Taken)	38.223 seconds	**33.303 seconds**
Stable Diffusion 1.5 ONNX (Image Generation Speed)	2.389 seconds/image	**2.081 seconds/image**

GEAR of the YEAR

We bestowed a record number of products our "Kick Ass" award in 2024. Welcome to our guide of the best tech of the year

ON THE FACE OF IT, 2024 hasn't been a banner year in PC tech. Sure, there were new GPUs in the form of Nvidia's SUPER and AMD's GRE updates, but they were mid-cycle refreshes rather than generational leaps forward. Meanwhile, in the CPU space, both Intel and AMD released new chips in the form of the Core Ultra and Ryzen 9000, but both were met with a collective shrug. Sure, they were more power efficient, and came with vaguely defined AI smarts, but they only offered a small performance boost, and in the case of Intel, a step backward in some tasks.

So it's no surprise that none of our headline categories—*Maximum PC* bread and butter like CPUs and GPUs—feature on our Gear of the Year list. But in other categories, things have come on leaps and bounds. Our builder, Zak, has seen a plethora of cases that have astonished thanks to their ease of building, customization, and brilliant value for money.

Likewise, SSDs have matured to the point where you don't have to spend a fortune to get a great-value PCIe 4.0 drive, and if you do have the cash to spend on the latest 5.0 models, they're great, too. RAM has followed the same path—it's now easy to find great-performing DDR5 memory that's fit for whatever type of build you're attempting (low-profile, RGB), but doesn't break the bank.

Don't worry, though—it's not just components that have wowed us; laptops have made the list. There are also some high-scoring curveballs, including a handheld PC games console, a projector, and even an air cooler. These are the products that have earned our highest score this year—join us as we salute them. **–THE MAXIMUM PC TEAM**

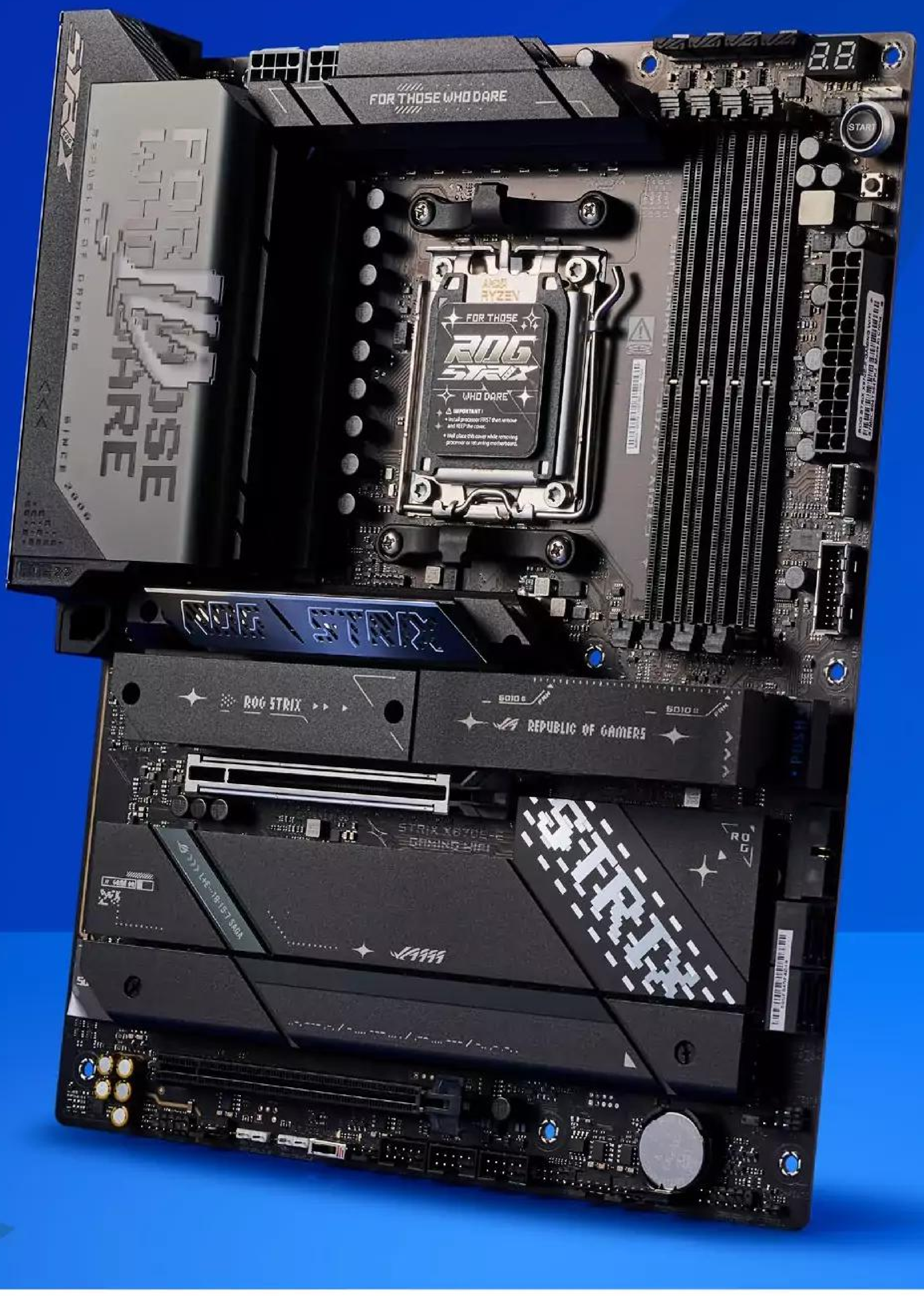
MOTHERBOARD

ASUS ROG STRIX X870E-E GAMING WIFI

As we mentioned in our intro, 2024's CPUs may not have impressed, but the motherboards that arrived to support them have—specifically this one. While it's premium at $500, it offers a no-compromise platform for your next AMD-based PC. What you're buying is enough PCIe 5.0 lanes to support the fastest transfers between your CPU and your GPU, SSD, and peripherals so that everything is maxed-out, speed-wise. Thanks to AMD's promised AM5 support up to 2027, you won't need to upgrade it for a good while yet, too.

● Price: $500 ● asus.com
● Reviewed: December 2024

★★★★★



HANDHELD GAMING PC

STEAM DECK OLED

★★★★★

How quickly the Steam Deck has gone from being a plucky disruptor to a must-have device for PC gamers. Yes, there have been many imitators, including some very good ones, like the Asus ROG Ally, but there's nothing quite like the original Steam Deck, and this OLED model is the definitive version. Boasting a vastly improved screen, 90Hz refresh rate, a larger battery, and many other smaller improvements, it's the device to take on any long journey—just as long as you have somewhere to plug it in, of course.
● Price: $549 ● steampowered.com ● Reviewed: February 2024

SSD

2TB LEXAR NM790 PCIE 4.0 M.2 SSD

790
Lexar
NM790
M.2 2280 PCIe Gen4x4 NVMe SSD

If you watch our 'Story of the Build' videos (always on page 17 each issue), then you'll know that we never stop going on about the Lexar NM790. For the majority of this year, it's been the best price-to-performance SSD money can buy, and while Samsung and WD have put the pressure on of late by getting 2TB drives down to almost $100, it remains a best buy. It may not be the latest PCIe 5.0 standard, but frankly, very few people need drives that fast—what this offers is great performance, solid endurance, and low temperatures and power draw—all for a superb price.
● Price: $121 ● lexar.com ● Reviewed: July 2024

★★★★★

SSD

2TB KINGSTON FURY RENEGADE PCIE 4.0 M.2 SSD

There are a few things to like about this SSD, which was built with Sony's PlayStation 5 console in mind (hence the heatsink). First of all, there's the endurance rating, which lasts for five years or 2,000 TB written. It stays exceedingly cool, even during prolonged transfers. It's also a stellar performer when it comes to Random 4K writes, even beating out much more expensive PCIe 5.0 drives. That means that while it may have been designed for the PS5, it'll make an excellent system drive for us PC enthusiasts. Thanks, Kingston!
● Price: $187 ● kingston.com ● Reviewed: May 2024

★★★★★

PCIe 4.0 NVMe M.2
KINGSTON
FURY
RENEGADE

SSD

GIGABYTE AORUS GEN5 12000 2TB SSD

Look at this thing! If SSDs aren't usually thought of as the most exciting components, then no one told Gigabyte. Sitting beneath that ginormous heatsink is a PCIe 5.0 drive that's so fast, it'll make your eyes water. We were able to achieve 12GB/s sequential transfers as advertised, and while the price tag is roughly double what you'd pay for a PCIe 4.0 drive, it's actually pretty reasonable for PCIe 5.0. You can also easily remove that huge heatsink using a Philips screwdriver without voiding any warranties.

- Price: $260 ● gigabyte.com
- Reviewed: March 2024.

★★★★★

AORUS
TEAM UP. FIGHT ON.
AORUS

SSD

2TB CRUCIAL T500 M.2 228 SSD

crucial
by Micron
T500
PCIe® Gen4 NVMe™ M.2 SSD

Our final PCIe 4.0 SSD is on this list for the same reasons as the Kingston Fury Renegade and the Lexar NM790—great performance, a strong five-year warranty, and a really keen price point. Like the Kingston drive, its low-profile heatsink is intended for PlayStation 5 consoles, but you don't need to worry about that, as it's brilliant for PC use, too. This drive does particularly well on sequentials, meaning that it's good for transferring large files. The only drawback is that it's difficult to remove that heatsink, should you ever need to get it into a laptop.

● Price: $149 ● crucial.com ● Reviewed: April 2024

★★★★★

MEMORY

32GB CRUCIAL PRO OVERCLOCKING DDR5

There's something reassuringly boring about this memory kit from Crucial—there's no RGB lighting or obnoxious logos; just matte black heatsinks covering the memory inside. But the product itself is anything but dull—it's extremely well-priced, works brilliantly across both AMD and Intel systems, and performs incredibly well overall. It's also a low-profile kit, making these sticks perfect for a compact build. If you need 32GB of memory for your next build, then this is as close to a no-brainer as we can offer.

● Price: $105 ● crucial.com ● Reviewed: June 2024

★★★★★

crucial by Micron
crucial by Micron

CPU COOLER

NOCTUA NH-U9S CHROMAX.BLACK

There may not be any liquid-based all-in-one coolers on our Gear of the Year list this year, but there is this tiny stealth powerhouse of an air cooler. It has a super-small footprint, which makes it suitable even for more compact builds; it's super quiet, and it worked on every CPU socket we could find. But the best thing about it is the performance—it keeps any chip that it mounts super cool, including top-end Ryzen 9 9950X and Core i9-14900KS CPUs. For $70, you can't ask for more than that.

● Price: $70 ● noctua.at ● Reviewed: December 2024.

★★★★★

LAPTOP

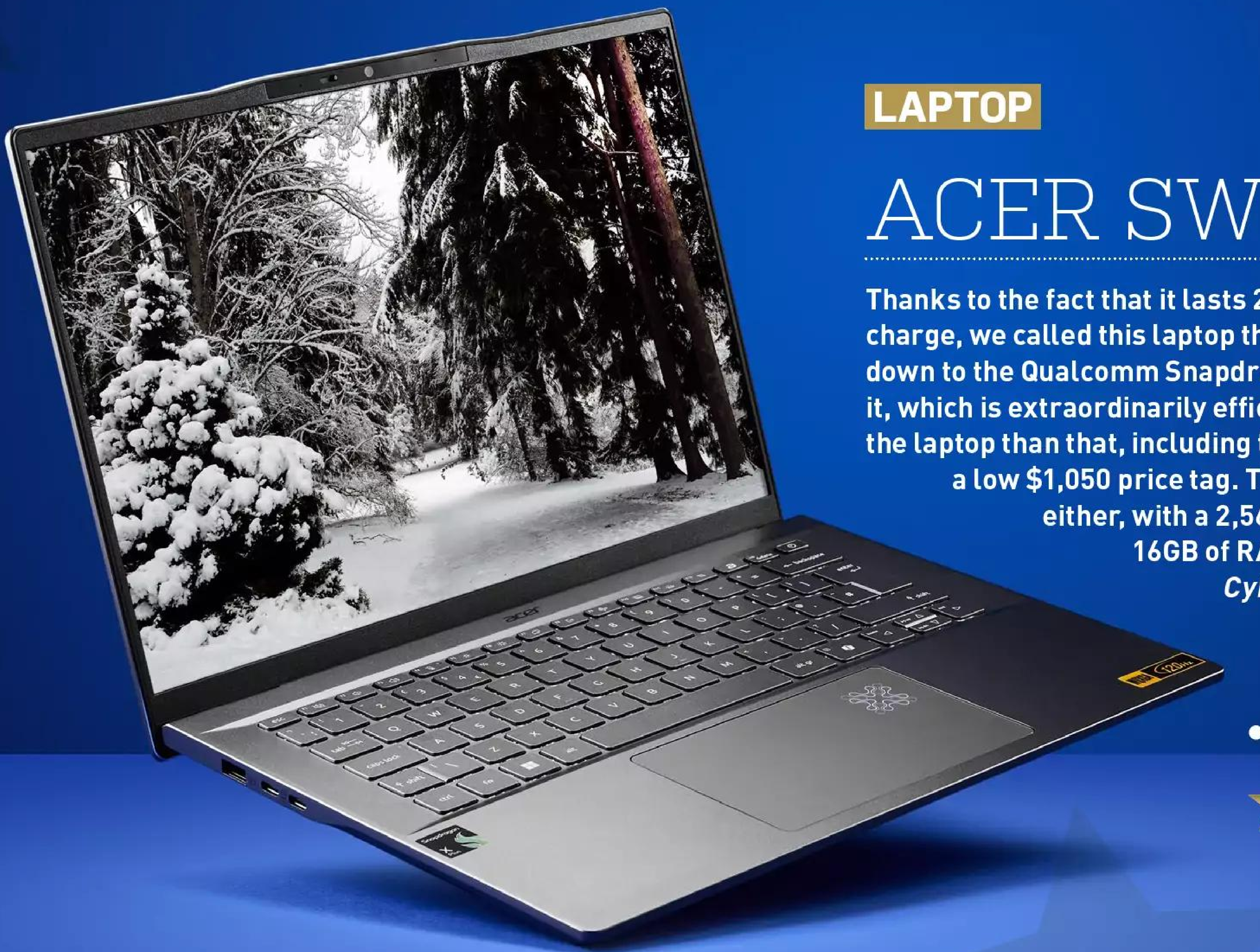
ASUS VIVOBOOK S 15 COPILOD

ASUS VIVOBOOK

Writers like Zak Storey and Jeremy Laird have written extensively this year about how good Qualcomm's mobile chips are, and the fact that the only laptops in our Gear of the Year list are powered by their chips is proof of that. This Asus is the more powerful of the pair, with the Snapdragon X Elite chip at its core, but it still offers unbelievable battery life (18 hours). The gorgeous 15.6-inch OLED display is another reason to choose this model, as is the premium build quality.

- Price: $1,270
- asus.com
- Reviewed: September 2024.

★★★★★



LAPTOP

ACER SWIFT 14 AI

Thanks to the fact that it lasts 26 hours without needing a charge, we called this laptop the "battery life king". That's down to the Qualcomm Snapdragon X Plus chip powering it, which is extraordinarily efficient, but there's more to the laptop than that, including top-tier build quality, and a low $1,050 price tag. There's no corner-cutting, either, with a 2,560 x 1,600 90Hz screen and 16GB of RAM, and it'll even play a bit of *Cyberpunk 2077*. With specs like those at just over a grand, why choose anything else?

- Price: $1,050
- acer.com
- Reviewed: Holiday 2024.

★★★★★

CASE

GEOMETRIC FUTURE MODEL 4 CALIBURN

If you want a full-size case that won't completely dominate the room that it sits in, then the Geometric Future Model 4 Caliburn is your best choice. Unlike, say ,the company's Model 5 case that's also on our list, the Model 4's mirrored exterior is sleek and unassuming. But it's also still big enough to house any motherboard you want to throw in it, not to mention any 360mm rads and oversized GPUs you might have as well. If you want a sleek-looking PC, then this is the case to build in.

● Price: $109 ● geometricfuture.com
● Reviewed: August 2024.

★★★★★

CASE

NZXT H7 FLOW

We've long been a fan of NZXT's cases, as can be witnessed by their regular appearances on our covers (two this year). But while we had some issues with the 2024 version of the H5 Flow, specifically the inability to top-mount a 360mm rad, we have no such complaints about the H7 Flow. It's about as easy and roomy to build in as is possible, the cable management is impeccable, there's a plethora of cooling options, and in keeping with the theme of cases in 2024, it offers spectacular value for money.

● Price: $130 ● nzxt.com
● Reviewed: September 2024.

★★★★★

CASE

HYTE Y40

Hyte's Y70 Touch was the star of our January issue, which was one of our most impressive covers, thanks to the case's built-in touchscreen capable of running Windows, if you were so inclined. The Y40 is much more simple (and cheaper) than its bigger brother, but it still impresses. You're forced to mount your GPU vertically, but that's fine, as the package comes with the required mount. In fact, most systems benefit from these aesthetics, which really is this case's priority—to make your components look as good as possible. Mission accomplished.

● Price: $150 ● hyte.com
● Reviewed: April 2024s.

★★★★★

CASE

PHANTEKS XT VIEW

If there was an award for Best Value this year, then the Phanteks XT View would win it. It quite frankly feels like a steal to be paying just $80 for case that offers a fashionable fishbowl design, feels this high quality, and even has RGB accessories in the box. There are no corners cut, either, with USB C, USB 3.0, and even an RGB controller included. What's more, it pulls off the TARDIS-like feat of feeling quite compact, but actually being big enough to fit in a large E-ATX motherboard, if you so desire.

● Price: $80 ● phanteks.com
● Reviewed: August 2024.

★★★★★

CASE

GEOMETRIC FUTURE MODEL 5

The cover star of this very issue, the exceedingly green Geometric Future Model 5 (other colors are available) is the case that has it all for just $150. Featuring the fishbowl design that has become so popular this year, plus five RGB fans included (with room for 10 total), and discrete GPU support, it offers everything that a builder in 2024 and beyond needs. It's also an absolute joy to build in, with ample space for any super-large motherboard or GPU you'd want to throw in it while keeping everything nice and tidy.
● Price: $150 ● geometricfuture.com
● Reviewed: Holiday 2024.

★★★★★

GEOMETRIC FUTURE
MODEL
05
GEOMETRIC FUTURE

CASE

NZXT H6 FLOW

Another budget case to gain our accolades this year, even if it's not quite at the bargain-basement levels of the Phanteks XT View. It also doesn't quite have the cable management design we like so much about the H7 Flow, but then again, it's $20 less. What you get here is a supremely well-designed case that's made of quality materials, and shows off your system internals without going over the top. And as the name suggests, the airflow in this case is excellent, thanks to having fan space in the front, top, rear, and bottom.
● Price: $110 ● nzxt.com
● Reviewed: May 2024.

★★★★★

PROJECTOR

XGIMI HALO+

We're fans of a great story-driven single-player game here on *Maximum PC*, and there's nothing like playing one of those on a giant projector-driven screen, if you're able to. XGIMI has been doing more than anyone else to make projectors appealing to the PC market—there's obviously that low $700 price, but the 1080p picture is excellent, especially in HDR10 mode, and it's supremely portable as well. You don't even need a PC to drive it—Android TV built in allows you to stream movies and games from the internet, no peripherals required.

● Price: $700 ● xgimi.com
● Reviewed: June 2024.

★★★★★

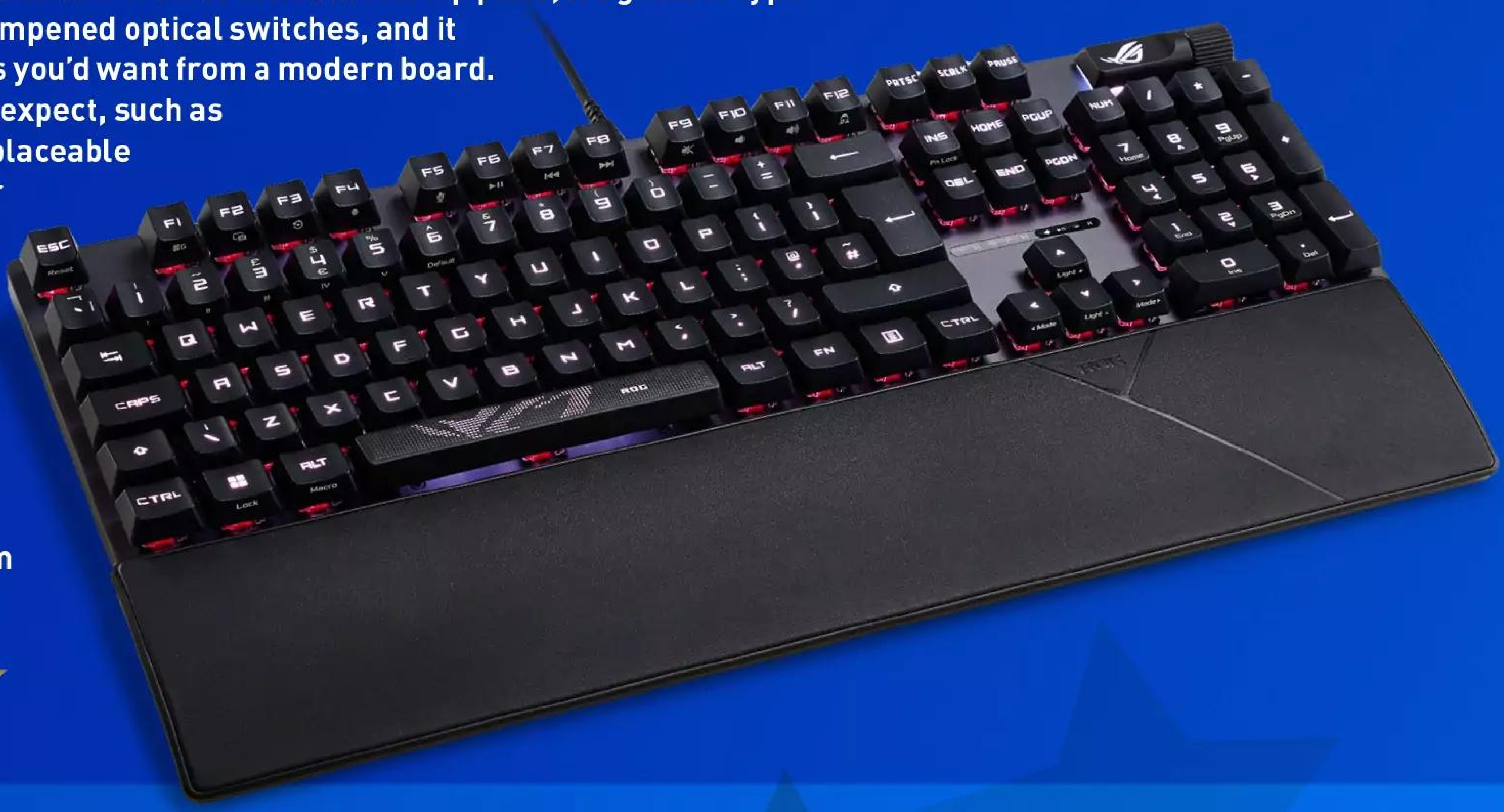
KEYBOARD

ASUS ROG STRIX SCOPE II RX

The only keyboard on our list this year comes from Asus, a company not exactly known for its typing peripherals. So what's the draw? Well, it just gets all the basics right—it feels sturdy and premium thanks to its brushed metal top plate, it's great to type on thanks to its sound-dampened optical switches, and it has all the media controls you'd want from a modern board. It also has stuff you don't expect, such as pre-lubed switches, a replaceable space bar, and IP57 water and dust resistance to keep things nice and clean. The cherry on top is the price, which is much less than flagship boards from the likes of Corsair and Razer.

● Price: $140 ● asus.com
● Reviewed: June 2024.

★★★★★



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ASUS Zenbook

INTEGRATED GRA

Intel Lunar Lake takes on AMD

GAMING LAPTOPS have grown in popularity over the years, but they're often heavier and noisier than models that use integrated graphics. AMD and Intel have both released new mobile processors in recent months, with beefed-up GPUs that have taken over the budget sector of the graphics market.

It's telling that we haven't seen much in the way of new budget mobile GPUs in the past few years. Nvidia still offers older Turing and Ampere-derived solutions in the MX550 and MX570, but without any of the RTX features, like DLSS and ray tracing. Those were both launched in March 2022, but if you only need that level of

Intel's Lunar Lake represents the most potent iGPU Intel has ever created, providing a decent bump over the prior generation Meteor Lake, and even taking down AMD's current top 16 CU solution.

PHICS SHOOTOUT

Strix point for mobile supremacy

graphics performance, you might find that the latest iGPUs from AMD and Intel are sufficient.

We collected three similarly configured laptops and put them through a gaming test suite to see how well the latest integrated graphics solutions perform. We also ran benchmarks on a gaming laptop with a dedicated RTX 3050 Ti as a point of comparison, but there are caveats with that system that we'll cover in a moment.

Turn the page, and we'll discuss the major selling points of the latest processors and see how they stack up. –**JARRED WALTON**

MEET THE CONTENDERS

Zenbook S16

CODENAMED STRIX POINT, AMD's latest mobile processors come with Ryzen AI branding—the AI is for the integrated NPU and support for Copilot+, with the NPU offering up to 50 TOPS of INT8 compute. On paper, it's easy to see this as the laptop to beat, as far as gaming performance on integrated graphics goes. AMD has far more experience in the graphics arena, both with the GPU hardware and the drivers that make the GPU work.

The HX 370 processor sits close to the top of AMD's current mobile product stack, with 12 CPU cores (four Zen 5 and eight Zen 5c), and Radeon 890M graphics. There's an HX 375 as well, but the only difference is 55 TOPS from the NPU instead of 50 TOPS, and we're focused on the iGPU for this investigation.

The Radeon 890M features the RDNA 3.5 architecture, which is basically RDNA 3 plus some efficiency optimizations to improve battery life and performance. It comes with 16 Compute Units (CUs)—33 percent more than the previous generation 780M and 680M solutions. It also clocks at up to 2,900MHz in theory, which gives it a potential 5.94 teraflops of FP32 compute. In practice, across our 24 game test suite, the 890M averaged closer to 2,000MHz, plus or minus around 200MHz, depending on the game. That drops real-world compute down to around 4.10 teraflops.

ASUS Zenbook
ASUS Zenbook

Asus's Zenbook S16 with AMD Ryzen AI 9 HX 370 comes with a larger 16-inch chassis and screen, but don't worry, we tested it with the same 28W power limit as the smaller Intel laptops.

The Asus Zenbook S14 features Intel's latest Lunar Lake processor, with a 14-inch display, but faster LPDDR5x-8533 memory.

Asus ships the Zenbook S16 with 32GB of 7500 MT/s LPDDR5x memory, which provides 120 GB/s of shared memory bandwidth. AMD officially supports up to LPDDR5x-8000 on the processor, which could potentially boost performance by another 6.7 percent, but ultimately it's up to the laptop manufacturers to decide which memory to use. All three Asus laptops we're testing also have the RAM soldered down, so there's no potential for memory upgrades down the road.

Zenbook S14

THE LATEST LAPTOP in our roundup is the Asus Zenbook S14, featuring Intel's Core Ultra 7 258V processor and Arc 140V graphics. Curiously, there's a supposedly faster Core Ultra 9 288V processor, but early indications are that it's underperforming—we ran some benchmarks, and in several instances the 258V outperformed the 288V. Oops. Small wonder then that there are at present no Core Ultra 9 288V-equipped laptops shipping in the US, though several could show up in the coming months.

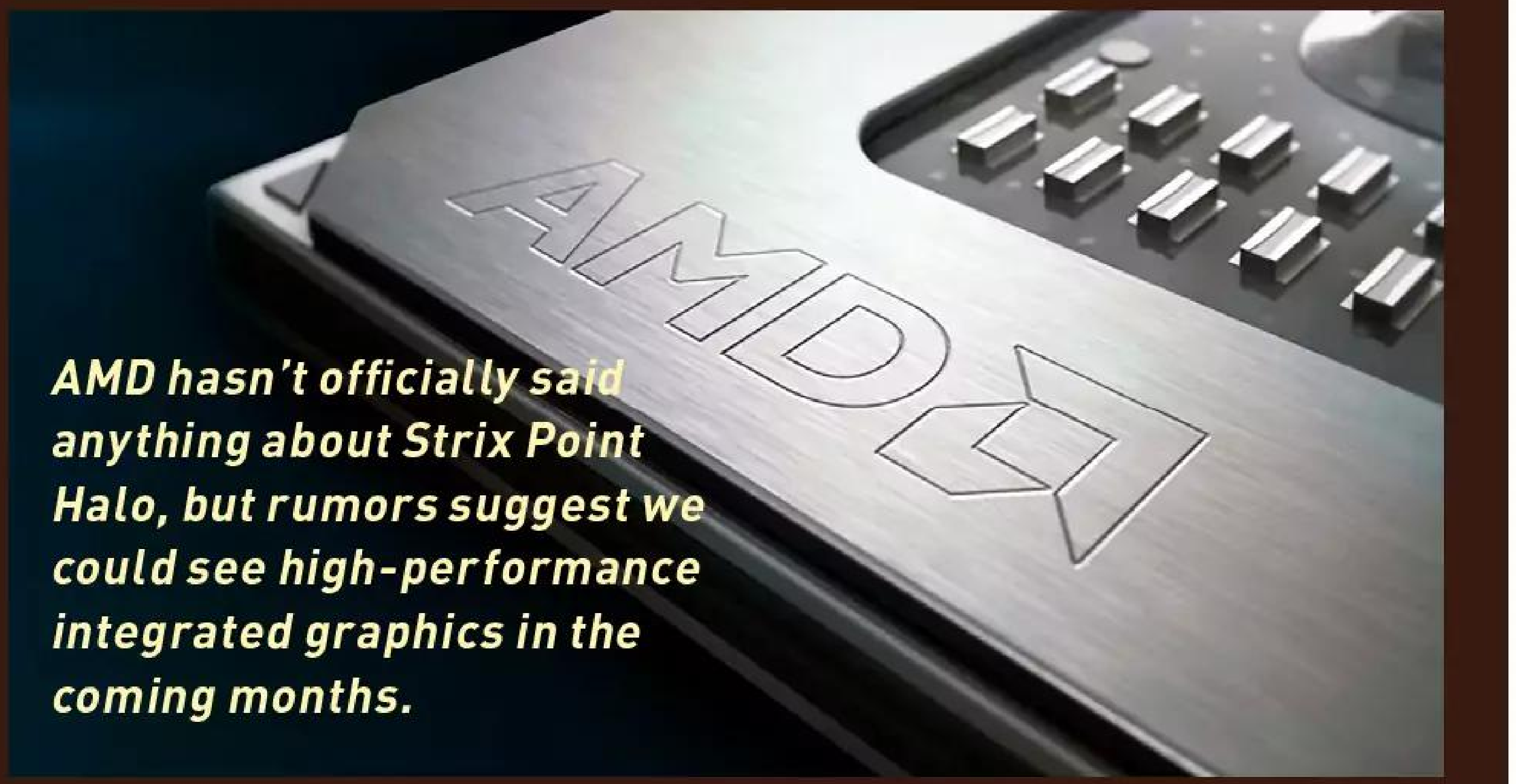
Lunar Lake processors are manufactured by TSMC using the cutting-edge N3B node for the CPU and GPU tile, with a second Platform tile that handles IO and other aspects that's fabbed on the

AMD STRIX HALO INCOMING?

AMD knows how to make far more powerful integrated graphics solutions than the Radeon 890M used in the Ryzen AI 9 HX 370. It's been doing so for years—look no further than the Xbox and PlayStation. The Xbox Series X packs a 52 CU GPU, while the PS5 has a 36 CU GPU—and the new PS5 Pro has a 60 CU graphics solution. So why don't we ever see anything like that for Windows PCs?

The biggest reason is economies of scale. AMD knows it will sell tens of millions of chips to Microsoft and Sony, so the cost per chip comes way down. If it were to build a similar processor for Windows PCs, would it sell? That's been a long-running debate in the PC community, but we might get a real-world answer with Strix Point Halo.

Rumors say it will feature up to 40 CUs, with a 256-bit memory interface. That second part is critical, as saddling a 40 CU graphics chip with the typical 128-bit shared memory solution of regular processors would restrict performance. Larger caches can help, but at some point, a GPU just needs more raw bandwidth.



AMD hasn't officially said anything about Strix Point Halo, but rumors suggest we could see high-performance integrated graphics in the coming months.

With LPDDR5x-8000 memory, Strix Point Halo could have 256 GB/s of bandwidth, which ought to be enough to keep the 40 CUs at least moderately happy. Do note that the PS5 has 448 GB/s, so AMD would need to work some magic to have such an iGPU deliver performance on par with the 32 CU RX 7600 XT or the 40 CU RX 6750 XT. But it's theoretically possible, and we're curious to see how this plays out.

© AMD, ASUS

ASUS Zenbook

The Asus Zenbook 14 OLED looks a lot like the S14, except it uses last year's Meteor Lake CPU. It also has LPDDR5x-7500 memory like the Ryzen AI laptop.

older N6 node. These are linked together on a Foveros tile made on Intel's old 22nm FinFET process (which launched in 2012, in case you're wondering).

The Core Ultra 7 258V is the least potent of the processors we're looking at in this roundup, insofar as the CPU goes. It has just four P-cores and four E-cores, with eight cores and eight threads total. That seems like a big step backward compared to the 16 cores and 22 threads provided by the previous generation Meteor Lake processors, not to mention the 12 cores and 24 threads on tap with Ryzen AI. But there's a method to the madness.

Most ultra-thin laptops end up being power constrained, so there's limited benefit to adding even more CPU cores when the chips have to run in a 28W or lower-power envelope. Intel has beefed up the graphics solution in Lunar Lake as well, which shares power with the CPU—and the two on-package LPDDR5x chips, for that matter. The RAM uses 1.5W, we're told, so technically even though total package power was similar, Lunar Lake has a 1.5W disadvantage.

The GPU has 8 Xe2 cores (aka Battlemage) and clocks at up to 1950 MHz, for a theoretical 3.99 teraflops. It's our first encounter with Intel's second-generation Arc GPU. And don't forget the memory, which offers 136.5GB/s of bandwidth.

Zenbook 14 OLED

To see just how far Intel has—or hasn't—come in the realm of integrated graphics performance, we also have a previous-generation Meteor Lake laptop. This Asus laptop leverages the Core Ultra 7 155H, with specifications that are otherwise very similar to the newer Lunar Lake system.

The only significant difference, other than the processor, is the use of LPDDR5x-7500 memory. Keep in mind that Lunar Lake puts the memory on-package, and Intel determines what memory to use, which could explain why the newer chip gets the faster RAM.

The Core 7 155H has six P-cores with Hyper-Threading, eight E-cores, and two low-power E-cores. In application testing, it often outperforms Lunar Lake, but Lunar Lake seems more focused on efficiency, battery life, and improved AI and graphics performance than on raw CPU number crunching.

The GPU consists of the first-generation Arc Graphics (aka Alchemist), with eight Xe-cores clocking at up to 2,250 MHz. Power constraints as usual limit clock speeds in practice, and the GPU averaged around 2,000 MHz in our testing—it was basically tied with the Radeon 890M on clocks in most cases. That means up to 4.61 teraflops of compute in theory, and closer to 4.10 teraflops in practice.

Incidentally, the Lunar Lake GPU averaged around 1850 MHz in our testing for just 3.79 teraflops of compute. However, as we'll see in the performance results, architectural differences and increased memory bandwidth seem to more than make up for the deficit.

Intel's Xe2 architecture at the heart of Lunar Lake focuses on improving performance and efficiency, aiming for higher utilization on average thanks to the SIMD16 ALUs. Geometry sees up to a 3X improvement, with twice the sampling throughput as well. Intel claims up to 1.5 times the performance of Meteor Lake at the same power, so let's see how that plays out.

WHAT ABOUT APPLE AND QUALCOMM?

You'll notice that we didn't do any testing of Apple or Qualcomm silicon. While Apple mostly rules itself out by virtue of not being able to run Windows natively, it has some serious integrated GPU performance. The M4 Pro has a 2560 shader GPU with a 256-bit memory interface that yields 273 GB/s of bandwidth, and the M4 Max doubles that to 5120 shaders and a 512-bit interface with 546 GB/s. M4 Max also offers 18.4 teraflops of compute, which puts it on par with an RTX 3070, at least on paper.

Qualcomm, for its part, has Windows on Arm support, so it does better at running games. The Snapdragon X Elite has a 12-core GPU that delivers 4.6 teraflops of performance. That seems to be what all the major players are aiming for as a baseline these days, as AMD, Apple, Intel, and Qualcomm all have such a solution.

But Qualcomm's gaming support has been pretty hit and miss so far. Besides the need for emulating x86 on Arm, Qualcomm also has to deal with graphics drivers. If you look back at Intel's Arc journey over the past couple of years, that's basically what Qualcomm faces as far as getting its drivers and performance up to snuff. Even then, a 4.6 teraflops iGPU isn't going to set the gaming world on fire, as shown by our benchmarks here.

Snapdragon
X Elite

The Qualcomm X Elite made a lot of noise about having amazing performance and battery life, but the reception has been muted, with plenty of complaints and returns.

There are over 1,000 games that run 'perfectly' or are at least 'playable' on the X Elite, but a large percentage consist of older games and smaller indie games that aren't very demanding.

© TOM'S HARDWARE

PERFORMANCE ACROSS 24 GAMES

INTEL CLAIMED that Lunar Lake could deliver 1.5 times the performance of Meteor Lake, and across an extensive test suite, that's reasonably close to our final results. Technically, Lunar Lake delivered 41 percent higher performance at 720p and 35 percent more performance at 1080p, but again, we note that it's using 1.5W less power.

Out of our test suite, there was only one game that failed to run properly with Intel's current drivers: *Star Wars Outlaws*. It completely failed on Meteor Lake, and crashed to desktop frequently on Lunar Lake. We were able to get a score at 720p, but there were rendering errors, and it clearly needs more driver work, which Intel says it's doing. We tested with versions 6130 for Meteor Lake and 6028 for Lunar Lake, and note that driver versions are not yet fully synced up. (At launch, the Lunar Lake drivers were months behind, so things have improved.)

The battle between AMD's Radeon 890M and Intel's Arc Graphics 140V ends up being extremely close. Lunar Lake technically gets the win, by seven percent

GAMES PERFORMANCE TESTING RESULTS

	Core Ultra 7 258V	Ryzen AI 9 HX 370	Core Ultra 7 155H
27 Test Geomean	**48 / 31**	45 / 29	34 / 23
Assassin's Creed Mirage (Low)	76 / 55	**85 / 56**	44 / 34
Avatar: Frontiers of Pandora (Low)	33 / 20	**34 / 21**	17 / 12
A Plague Tale: Requiem (Medium)	29 / 20	**41 / 23**	29 / 20
Black Myth: Wukong (Medium)	**43** / 19	39 / **24**	28 / 18
Baldur's Gate 3 (Medium)	48 / 32	**49 / 35**	34 / 26
Control (Medium)	**79 / 44**	65 / 34	62 / 30
Control (RT Medium)	**45 / 23**	39 / 21	39 / 22
Cyberpunk 2077 (Medium)	**50 / 35**	48 / 29	39 / 27
Cyberpunk 2077 (RT Medium)	**21 / 10**	10 / 5	17 / **10**
Dragon's Dogma 2 (Low)	33 / 26	**37 / 30**	24 / 19
Diablo IV (Medium)	**87 / 62**	82 / 53	72 / 49
Dying Light 2: Stay Human (Medium)	**62 / 44**	54 / 33	42 / 30
F1 24 (Medium)	100 / 78	**119 / 86**	71 / 58
Final Fantasy XVI (Low)	**24 / 15**	23 / 14	18 / 12
Flight Simulator (Medium)	**59 / 34**	51 / **34**	45 / 27
God of War: Ragnarök (Low)	**42 / 32**	29 / 22	20 / 16
Hogwarts Legacy (Low)	**70 / 43**	55 / 39	40 / 29
Horizon Forbidden West (Medium)	**42** / 33	38 / **35**	35 / 27
MechWarrior 5 Clans (Low)	**34 / 21**	28 / 18	23 / 16
Spider-Man: Miles Morales (Medium)	**74 / 56**	66 / 48	54 / 37
Minecraft (50 Chunks)	**152 / 148**	143 / 113	106 / 92
Minecraft (8 RT Chunks)	**35 / 17**	27 / 13	30 / 16
Star Wars: Outlaws (Low)	27 / FAIL	**32 / 21**	FAIL / FAIL
Starfield (Low)	**33 / 24**	**33 / 24**	17 / 13
The Last of Us, Part 1 (Low)	41 / 28	**48 / 30**	35 / 25
Warhammer 40,000: Space Marine 2 (Low)	**45** / 29	44 / **31**	35 / 25
Witchfire (Medium)	55 / 35	**62 / 40**	44 / 30

Best scores are bolded. Testing at 720p/1080p with low or medium settings. Each laptop has 32GB of shared memory and a fast 2TB SSD. Failures proportionally scale the overall geomean, so one failure drops the overall score by 3.7% (26÷27).

overall, but the two iGPUs trade blows across our test suite. Several of the games were also still unplayable, even at 720p with low settings. If we ignore the three games where ray tracing was enabled, *Final Fantasy XVI* and *MechWarrior 5 Clans* are the two worst offenders.

We also mentioned comparisons with a gaming laptop with a dedicated GPU, though caveats are in order. We used a Dell G15 (5520) that's equipped with a Core i5-12500H CPU, RTX 3050 Ti GPU, and a single 8GB DDR5-4800 memory stick. Memory proved to be the worst sticking point, and *The Last of Us* refused to run on the laptop—we said when it was announced that the RTX 3050 Ti with 4GB of VRAM was going to be problematic, and several years later, it's really starting to age.

While there was one failure to run, overall the RTX 3050 Ti still provided 44 percent more performance than Lunar Lake at 720p, and 61 percent better performance at 1080p. A more recent GPU like the RTX 4050 would likely increase the margin of victory. But here's the important bit: the Dell laptop used a combined 115W of power across the CPU and GPU (not counting display and other components), compared to 28W for the three laptops we've focused on here.

As you can probably guess, battery life on a gaming laptop will be significantly worse than on any of these thin and light laptops. If you're looking for good battery life while playing games, you'd be far better off using a game streaming service like GeForce Now.

CONCLUSION

LAPTOPS continue to gain market share relative to desktops, though for gaming and graphics performance, desktops still reign supreme. That's not really our point here, though. We're more interested in just how far integrated graphics have come over the past several years.

Intel used to be the worst graphics solution by far. Back when Ice Lake launched in 2019, I remember trying to test the potential gaming performance of the Core i7-1065G7. Roughly a third of the games I tried either failed to run entirely, or ran with severe rendering errors. The Core i7-1165G7 'Tiger Lake' processor in 2020 was only moderately better, even though it was the first of the 'Xe Graphics' solutions.

Fast forward to 2024 with Arc, and we're down to just one failure out of 24 games (*Star Wars Outlaws*), and one other game (*Baldur's Gate 3*) that needs some driver tuning. (The game 'pulses' right now, with a fast-then-slow-then-fast cadence.) Perhaps more importantly, for the first time—probably ever, as far as we can recall—Intel's integrated graphics solution can legitimately lay claim to being the fastest Windows solution around. That might not last for too long, though we also question how many people are truly worried about higher iGPU performance.

Being the fastest iGPU for Windows doesn't mean Intel has the lead over every iGPU solution, of course. Apple's latest M4 chip, as an example, sports a 10-core GPU with 1,280 shader units and a theoretical 4.61 teraflops—not all that different from what we're seeing here. But the M4 Pro doubles that, and the M4 Max doubles it again. AMD isn't sitting still either, as there are credible rumblings that we could see Strix Point Halo in the coming months (see sidebar on page 46).

But for now? Lunar Lake has arrived, and while it doesn't win every gaming benchmark, and definitely doesn't win every CPU benchmark, overall it's currently the fastest integrated graphics solution for Windows. It's also great for battery life. Now, we just need to see what happens with future higher-wattage Intel CPUs, not to mention next year's Panther Lake. ⏻

GAME STREAMING VIA GEFORCE NOW

If you're thinking about getting a gaming laptop, you may want to consider grabbing a thin and light portable, and subscribing to Nvidia's GeForce Now streaming service instead. For $10 per month, you get up to 100 hours of gaming per month in up to six-hour sessions (which you can immediately restart after reaching the limit).

You'll get roughly the cloud equivalent of an RTX 2080 or 3080, depending on the server and data center you connect to—either of which are way faster than any of these integrated solutions. Alternatively, you can spend $20 per month for an RTX 4080 equivalent. The best bit is that your laptop only needs to do video decoding, which means you can legitimately stream games for hours at a time without having to plug in.

But there are also caveats, the biggest being the need for a reliable high-speed internet connection—I've tried it, and hotel internet usually isn't going to cut it, and neither will tethered cellular connections, assuming you even want to use all that data. You'd basically be using around 10GB of data per hour for a 1080p 60fps stream.

If you have good home internet with no data cap, you can sit on your couch or in your bed and play games. Except then, you're stuck trying to figure out a comfortable way to use a mouse. Move to a desk, and you're only seconds away from plugging in a power cable. But hey, $10 per month on a $600 laptop means it would take about five years to reach the cost of a typical modest gaming laptop with an RTX 4060.

You can get a great gaming experience on a laptop via Nvidia's GeForce Now—A Plague Tale: Requiem runs very nicely at 1440p ultra settings, with 120fps on the Core Ultra 7 155H.

CENTERFOLD

PERFORMANCE GEAR LAID BARE

MSI Titan 18 HX

THIS MIGHT BE—at least right now—the world's most ridiculous laptop. It is insane—absolutely beyond comprehension. To put it bluntly, it starts at $5,500 just to get your foot in the door. To max out the spec, the price can go as high as $9,500. That's just insanity in an 18-inch form factor.

Why the big cost? Simply put, MSI has crammed every single element it can into this thing. It's got an Intel Core i9-14900HX processor—basically the same as the desktop equivalent, minus 200Hz. There's a full-fat RTX 4090 driving graphics performance, 64GB of DDR5 supporting it (which you can max out 192GB, if you so desire), and 4TB of PCIe 4.0 storage (with capacity for up to 24TB if you go for the ridiculous edition), all backed up by a wild 3,840x2,400 4K+ 120 Hz MiniLED IPS display.

The fact that MSI has managed to cram as much as it has into this thing is otherworldly. It drives exceptional performance, and MSI has eked out every facet of that, thanks to the help of some incredibly well-built cooling. This is a gaming laptop that delivers, But then, for $5,500, it absolutely needed to. It's not good value for money, that's for sure, and it's got some questionable aesthetic picks, but those aside, it's still impressive. **–MAXIMUM PC**

4K
steelseries | CHERRY

1 TOP TIER INTEL PROCESSING

This isn't a low-powered ultra-efficient Ultra core; this is a full-fat 5.8 GHz 14900HX, complete with hyperthreading and 24 cores of pure awesome. Cinebench scores rival desktop equivalents—all in this tiny form factor.

2 NATIVE RESOLUTION POWERHOUSE

At 4K in the latest titles, the Titan 18 HX easily punches out 50-60fps in *Total War* and *Cyberpunk* with a little help from its AI upscaling tech. Admittedly, the mobile 4090 is more akin to a desktop RTX 4080, but aside from that, it's impressive enough for us to let it slide.

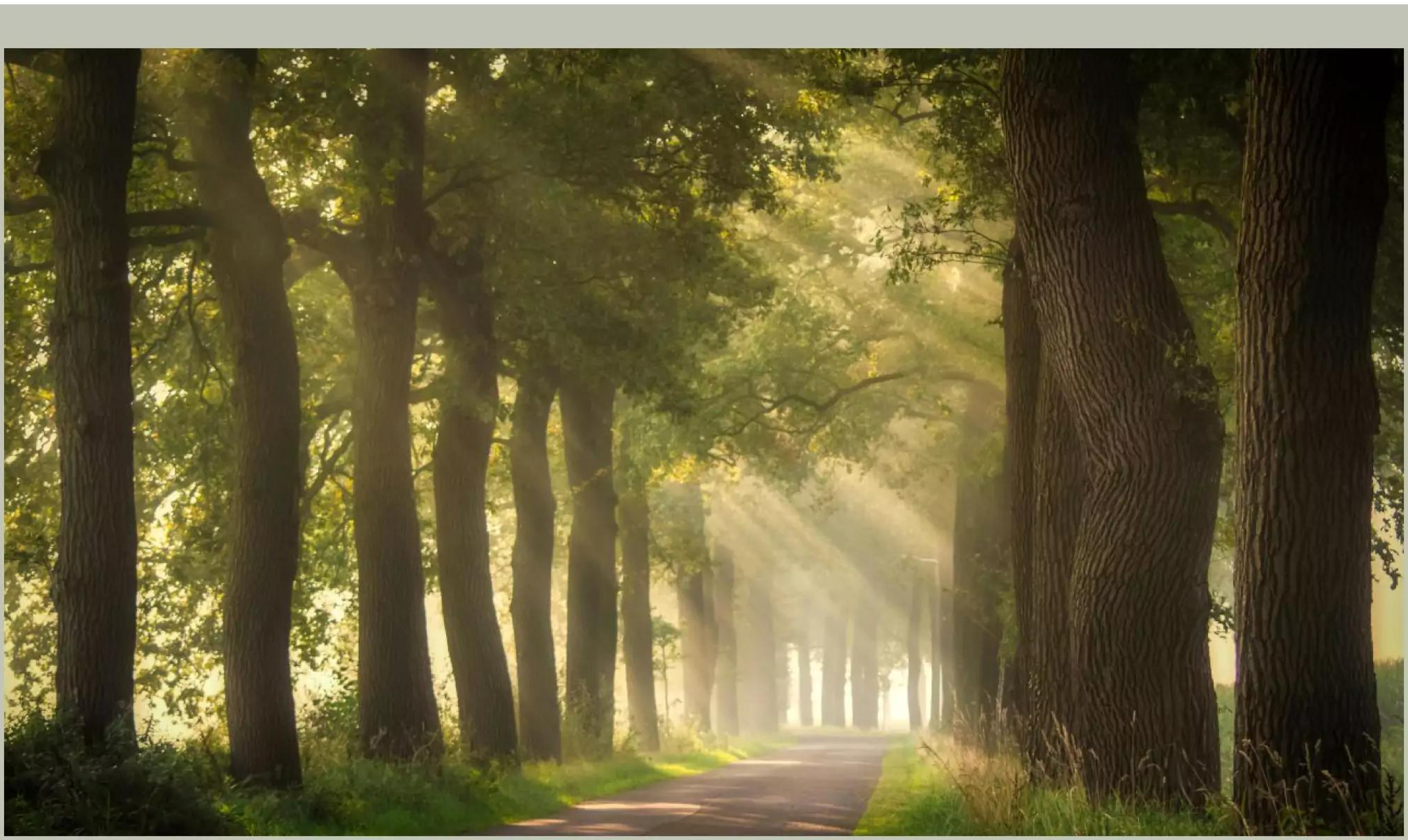
120Hz MINI LED GAMING DISPLAY
msi

3 NOT ON THE LIGHT SIDE

At 18 inches wide and 7lbs 15 ounces in weight, this thing is a true monster, but it needs to be. Not only does it have one heck of a cooling system inside, it's also got a 99.9 WHr battery nestled in there. Does it last long off charge? Nope!

4 FULL-SIZE MECHANICAL KEYBOARD

You read that right—MSI has worked with both SteelSeries and Cherry to create a fully mechanical keyboard. You get a full tactile experience, deep key presses, and rapid actuation.



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A BRIEF HISTORY OF RAY TRACING

Nate Drake discovers how ray tracing was implemented in computer graphics and revolutionized art, movies, and video games

IN 1525, THE GERMAN PAINTER and engraver Albrecht Dürer pioneered a new method for creating art. It involved using a grid and a piece of string to accurately trace the movement of light from 3D surfaces onto the 2D plane of a canvas.

Dürer correctly recognized that light travels in straight lines, so the string could represent the path of light from the image to the observer's eye. The artist could then make a series of marks on the picture to represent areas of high and low contrast. This was one of the first documented 'ray tracing' techniques, whereby an artist tried to realistically portray how light interacts with objects in different ways to produce an image.

Light doesn't behave this way in the natural world. In reality, photons emanate from light sources like a lamp, then bounce off different surfaces before reaching our eyes. This creates the world we perceive around us.

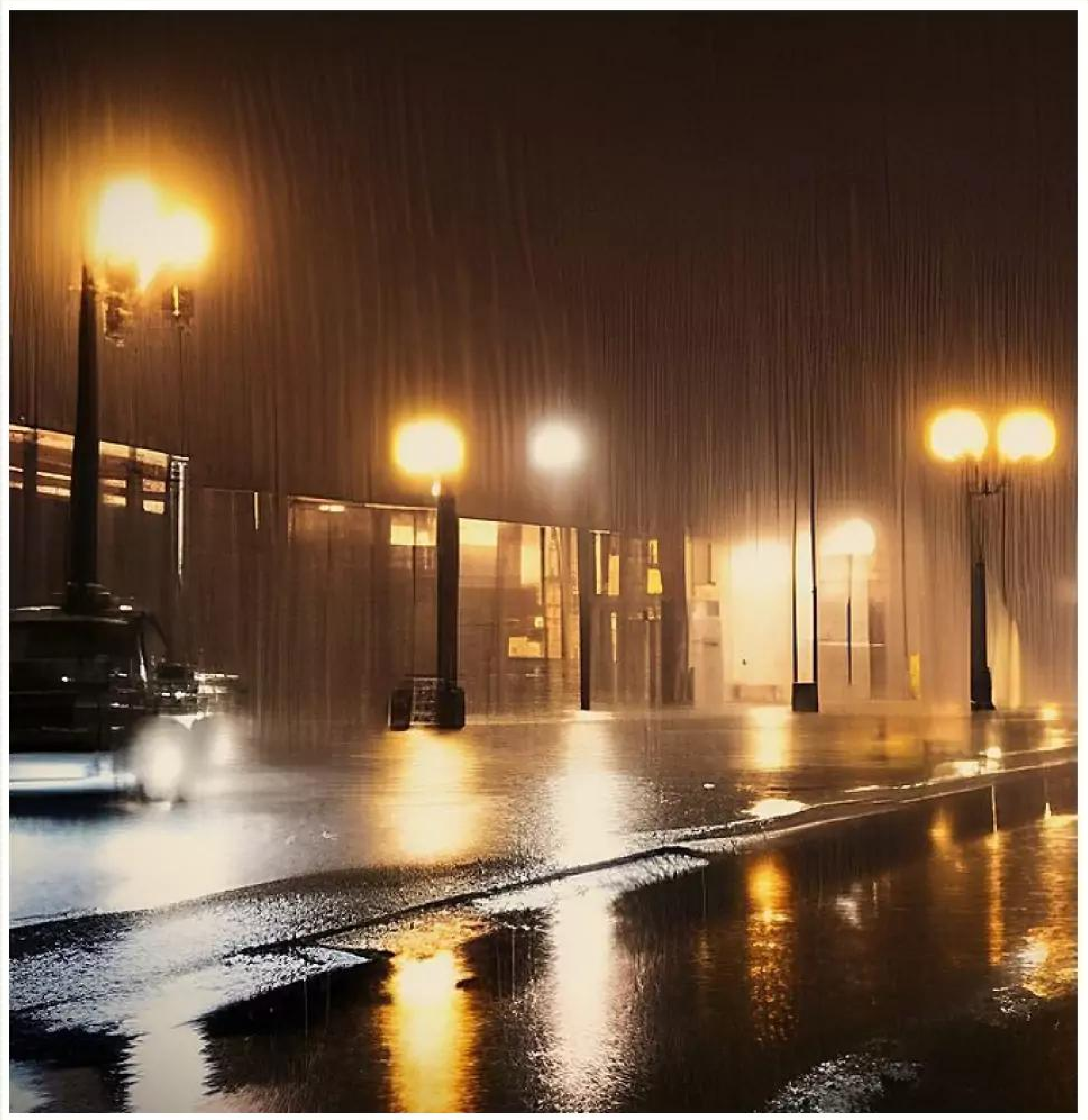
Ray tracing reverses this process. It simulates the path of light by tracing the movement of rays from the viewer's eye to an object, then to any light source. It also takes into account how light rays are reflected, refracted, or absorbed by any surfaces along the way. While this method is computationally very intensive, it can create extremely realistic images and videos that capture the subtle ways that light and shadow interact in scenes.

In this guide, we'll explore how ray tracing techniques evolved from a simple grid and piece of string, to the visually stunning movies and video games we see today.

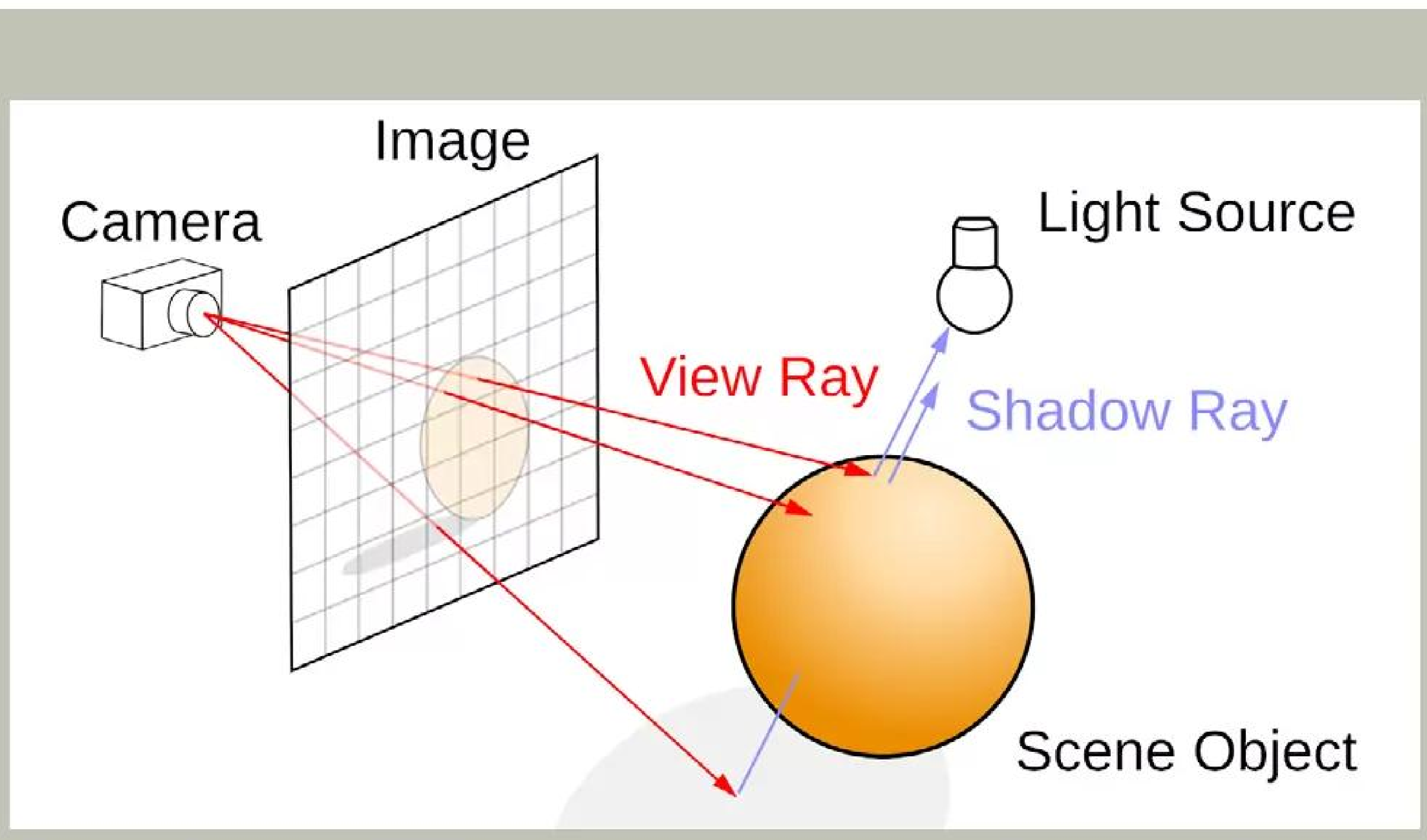
ORIGINS

As innovative as Dürer's string and grid method was, artists' work was made easier because they only needed to render a single image onto canvas. When computer graphics first emerged in the 20th century, lighting was initially a matter of programmers manually coloring pixels as they saw fit.

The first great leap forward for ray tracing occurred in late April 1968. IBM researcher Arthur Appel presented a paper at



In real life, light rays can interact multiple times with different surfaces, such as reflecting off a wet sidewalk.



Ray tracing extends light rays onto a scene from the viewer's perspective, then bounces them off surfaces toward light sources.

In this image of metal spheres, up to 16 reflections are allowed per ray, so reflections of reflections can be seen.

the spring 'Joint Computer Conference' titled 'Some techniques for shading machine renderings of solids'.

Appel acknowledged that computers had already made some gains in rendering wireframe models and other line drawings. However, he also pointed out:"Shadows, when sharply defined, tend to suggest another viewpoint and improve surface definition."

Appel proposed what is known today as a ray casting algorithm, though he referred to it as 'ray tracing'. This technique involved casting light rays from the viewer's eye through each pixel of an image on a plane. The intersections between light and objects in a scene could then be calculated to determine pixel color.

In 1980, computer scientist J Turner Whitted built on work like Appel's in a paper named 'An improved illumination model for shaded display'. Despite the rather dry title, this actually represented a huge advancement: Whitted had developed the very first algorithm for 'recursive' ray tracing.

Previously, ray tracing algorithms focused on a primary ray traveling from the viewer to surfaces and light sources. Whitted's algorithm took into account secondary rays. This allowed for mirror reflection and refraction through translucent objects for the first time, with an angle determined by the solid's index of refraction. This meant ray tracing could be used for improved anti-aliasing. To showcase this concept, Whitted produced a 37-second animated film, *The Compleat Angler*. This showcased a solid sphere orbiting a translucent one.

Another good way to imagine recursive ray tracing is to think of a rainy street in a small town at night. If a computer were to render a video of this, it would need to take into account the translucent store windows, full of merchandise.

It would also need to show reflective surfaces like puddles on the sidewalk. If it's night, the light sources are likely to be street lights at fixed intervals along the road. If a recursive ray tracing algorithm was used to depict this scene, it would first cast primary rays from the viewer's 'eye' through each pixel of the image plane. These would then interact with various elements of the scene.

For instance, if a ray was to hit the wet sidewalk, the algorithm might calculate a reflection ray. This reflection ray might, in turn, hit say the store window or a street light and capture their reflections on the wet surface of the sidewalk.

The algorithm can also calculate refraction rays for translucent surfaces like store windows, allowing viewers to see objects behind the glass in a realistic way. For each intersection point, like an area of the sidewalk, shadow rays can be cast. If an object like a mailbox blocks the path to the street light, that area will be in shadow, creating realistic-looking dark areas.

Whitted's algorithm allows for multiple 'bounces' of shadow and light, so a street light might be reflected in a puddle, then a store window, then finally reach the viewer's eye. This process happens recursively for each 'bounce' of light rays until a specified, preprogrammed depth is reached. Without this limit, the computer would keep rendering the scene indefinitely.

Whitted's creation inspired a series of innovations. This included one by graphics guru Robert Cook, who pioneered distributed ray tracing. This technique, introduced in a 1984 paper, works by precisely calculating ray directions.

IN COOK'S OWN WORDS

"By distributing the directions of the rays according to the analytic function they sample, ray tracing can incorporate fuzzy phenomena." This so-called 'fuzzy' phenomena allows for better rendering of blurred images and soft shadows, capturing nuances to better display how light interacts with real objects.

Cook and co-authors Thomas Porter and Loren Carpenter backed up their claims by producing a number of high-quality pre-rendered images to accompany the paper. However, doing so for a video was computationally infeasible. This is why distributed ray tracing wasn't immediately introduced into Pixar's 'RenderMan' software, which Cook co-authored. For example, the 1986 short film *Luxo Jr*was primarily rendered using traditional rasterization techniques. This was despite the film showing varying degrees of light and shadows as the lamps moved around.It wouldn't be until 1998's *A Bug's Life* that ray tracing would be used briefly for the first time in a Pixar film: to portray reflections and refractions on the surface of a bottle.

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11
97%
2 3 4
5 6 7
31
35 / 200
11 / 50
0 / 50
0 / 300
AMMO
HEALTH
ARMS
ARMOR

Many '90s games used rasterization to map objects and textures manually. Graphics cards were optimized to take advantage of this.

Battlefield V had the honor of being the first commercial video game to support real-time ray tracing.

OVERCOMING LIMITATIONS

As we've learned, the '80s laid the groundwork for the potential offered by ray tracing. However, some serious technical obstacles remained to implementing it in a practical way beyond pre-rendered images and video shorts.

In 1993, Stanford researchers Eric Veach and Leonidas Guibas published a paper called 'Bidirectional Estimators for Light Transport'. This was a rather unwieldy way of describing a new ray tracing technique that traced paths from both the viewer's eye and light sources to form a single light path. This was very useful for rendering scenes with a variety of indirect lighting, such as the aforementioned wet sidewalk illuminated by streetlights.

Throughout the '90s, software such as Pixar's RenderMan started to incorporate ray tracing techniques, though the underlying hardware was still unable to deploy it in an efficient way. This is because contemporary graphics cards were optimized for rasterization. For those readers who weren't '90s gamers, this technique was widely used in games of the era like the original *Quake*, as it struck a good balance between computational efficiency and realistic rendering.

Fundamentally, rasterization is the process of converting 3D isometric data like polygons into 2D pixel-based images. Typically, a small number of polygons were used to represent 3D objects. This was combined with techniques like Z-buffering and texture mapping to determine the detail and visibility of polygons. Although not nearly as realistic as ray tracing, rasterization allowed for easy scaling of graphics quality based on hardware capabilities. This was especially important in the Nineties, as there was a much wider disparity in hardware gaming performance on PCs than there is today.

However, said hardware could only handle a limited number of polygons, hence the rather blocky appearance of certain games of the era, like Lara Croft in the early *Tomb Raider* games. Many titles also used in-game 'fog' so they didn't have to render distant areas until they were needed.

It wouldn't be until the new millenium that ray tracing was seriously considered for gaming. In 2002, Stanford student Tim Purcell co-authored a paper called 'Ray Tracing on Programmable Graphics Hardware'. He and his fellow researchers created a simulator that demonstrated the feasibility of deploying ray tracing on (then) next-gen GPUs more efficiently than with CPUs.

In 2009, Intel announced the prototype of its 'Larrabee' GPU that was technically capable of real-time ray tracing. Nevertheless, the technique still remained mostly in the hands of filmmakers with access to supercomputers, though even that could prove a challenge. For instance, Pixar's *Monsters Inc* (2001) took 29 hours to render just one frame of film. The company was able to pull this off in a realistic amount of time through its own 'render farm' of 2,000 computers, each with 12 cores.

When the studio began work on *Monsters University* in 2013, Christophe Hery, the system's core architect noted in an interview with *The Verge*: "We had the full campus. We had the trees, the grass, the people, the crowds, all held in memory at once. At some point, the rendering engine can try to be clever about what doesn't need to be rendered, but you can only hide so much." This was despite the fact that each render farm machine had 96GB of RAM, which left little hope for casual gamers.

Still, in August 2013, Imagination Technologies developed the Caustic Professional's R2500 and R2100 plug-in cards. These contained RT2 ray trace units (RTUs), capable of calculating up to 50 million incoherent rays per second. In 2018, it became clear that ray tracing would soon be available to the masses. This was because Nvidia partnered with Microsoft DirectX to announce the Nvidia RTX Developer Library for its 'Volta' series of GPUs. To this day, one of the easiest ways to check if your Nvidia GPU supports ray tracing is if its name includes 'RTX'.

In September the same year, Nvidia introduced the GeForce RTX and Quadro RT series of GPUs, which used its 'Turing' architecture, capable of hardware-accelerated ray tracing. This meant the GeForce RTX 2080 and 2080 Ti became the first consumer-orientated graphics cards that were capable of ray tracing in real time.

In November 2018, an update was released for EA's *Battlefield V* to make it the very first commercial video game to use Microsoft's DirectX RayTracing API. Players who had the necessary GeForce card, graphics drivers, and game update were awarded a new in-game option for 'DXR raytrace reflections quality', which could be set between 'Low' and 'Ultra' to manage reflections in surfaces like windows and water. However, this came at the expense of game frame rates.

In October 2020, AMD also revealed the RX 6800, 6800 XT, and 6900 XT series of GPUs, all of which supported real-time ray tracing. The organizers of the online event weren't shy about comparing Nvidia's GPUs unfavorably with AMD's, highlighting superior performance in titles like *Battlefield V* and *Call of Duty: Modern Warfare*.

PRESENT AND FUTURE

Whether gamers were a fan of Intel or AMD, the first GPUs that supported ray tracing came with a hefty price tag. Even AMD's base RX 6800 was $549 ($665 in 2024 dollars). In a brilliant PR move, in June 2019, Nvidia released *Quake II RTX*. This was a source port of the original 1997 shareware version of the game that fully deployed ray tracing.

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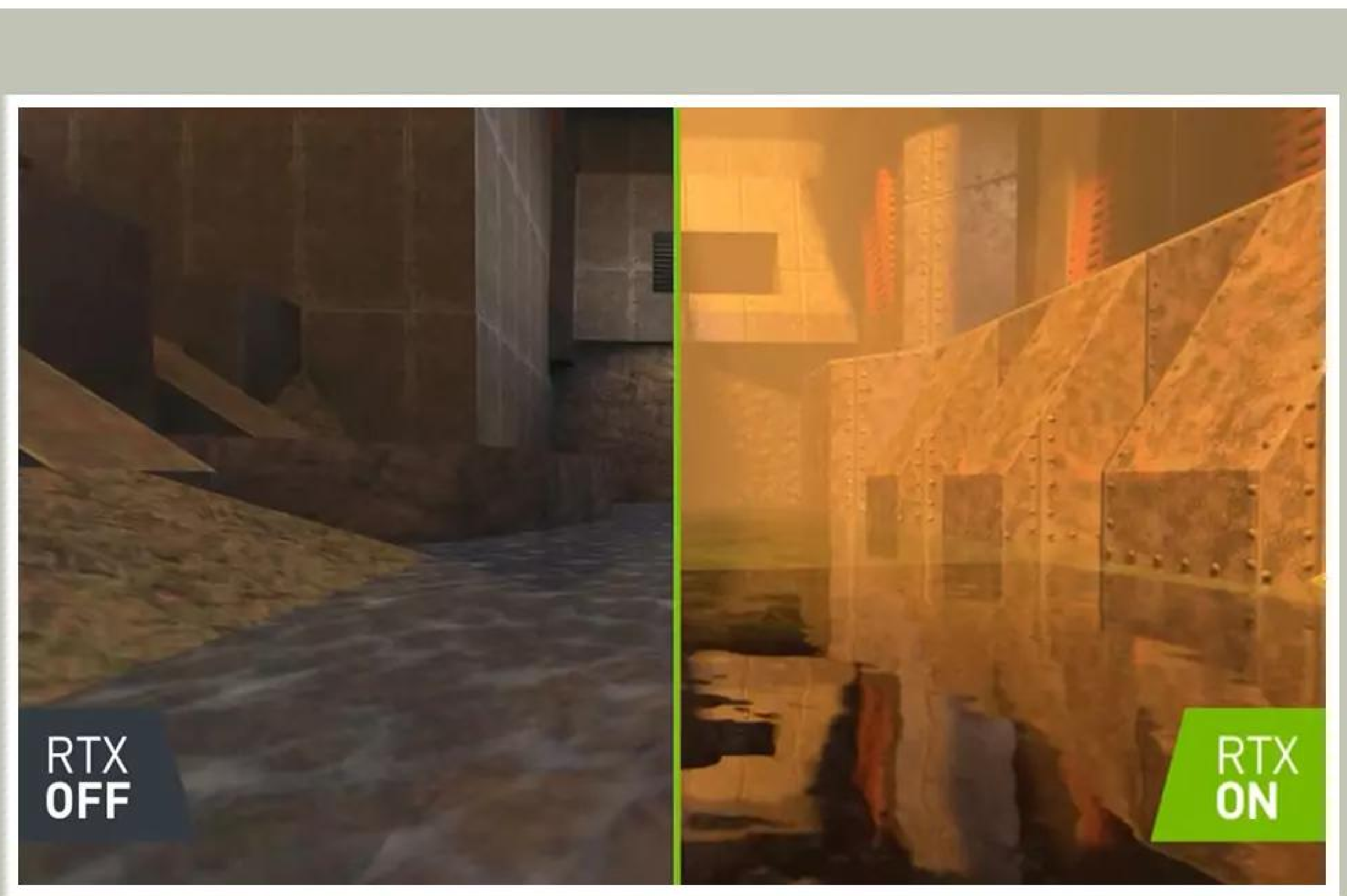
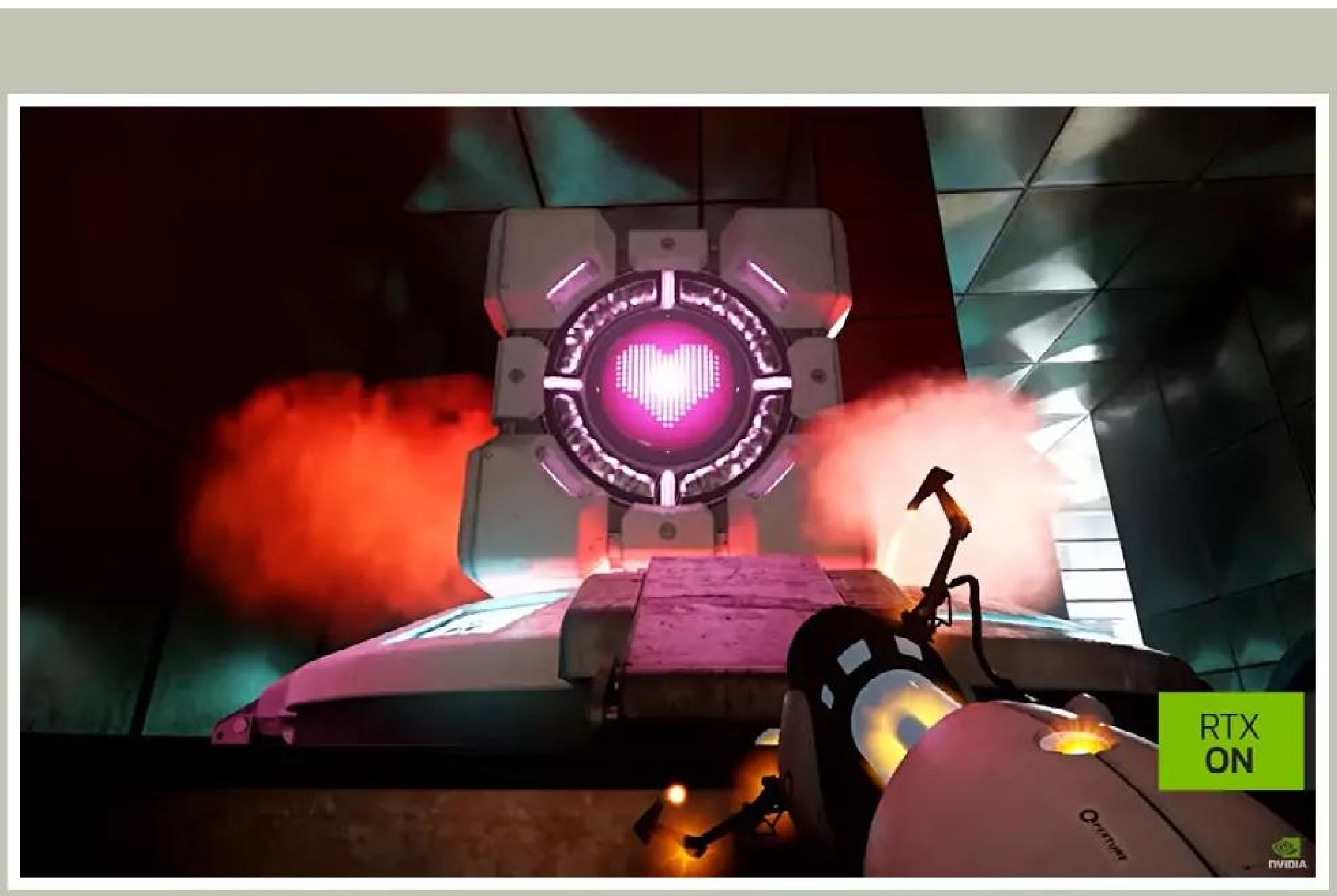


Nvidia cannily bigged up ray tracing in *Quake II RTX* by displaying the game both with and without it.



The RTX version of *Portal* displays subtle effects like indirect light from offscreen objects. Sadly, there is still no cake.

The official trailer teased the game running on a Vulkan renderer, showing gameplay with and without ray tracing. This updated version includes enhancements like real-time reflections of players and weapons on reflective surfaces like water. It also incorporated dynamic lighting for items like blinking lights.

In fairness, the game also owes its polished look to non-ray tracing aspects, like textures from the Q2XP mod-pack. Still, it's exciting to consider the possibilities ray tracing presents not just for new titles, but for giving older ones a new lease of life. Nvidia did that again in December 2020 with the release of *Minecraft RTX*, which added two new ray-traced worlds to the game.

In September 2022, Nvidia also announced the release of *Portal* (2007) with full ray tracing support. The game's former rendering APIs and system were replaced with RTX Remix's 64-bit Vulkan renderer. Fan mods also exist to simulate ray tracing effects on titles that don't have them natively, such as *Black Mesa*.

This reflects the fact that ray tracing is not supported by all current GPUs, and is demanding, even on modern hardware. It's also why many titles adopt a hybrid approach to game graphics. This usually involves combining traditional rasterization with ray-tracing to display effects like reflections and shadows.

Cyberpunk 2077 took this approach until May 2023, when players with compatible hardware could enable full path tracing in the game's 'RT Overdrive Mode'. In theory, path tracing can offer much more realistic gameplay than ray tracing alone. For instance, it calculates not just direct light, but multiple bounces and indirect reflections from rays interacting with different surfaces. This allows for effects like 'color bleeding', where colors from one object can reflect onto adjacent surfaces.

As light rays are scattered in many directions through path tracing, shadows can also be softer and look more natural. This has to do with how path tracing algorithms use random sampling to match real-world lighting. It's easy to imagine that everyone with compatible hardware switched to the full path-traced mode for *Cyberpunk 2077*, but this wasn't the case. Online reviewers pointed out that the performance improvement was minimal compared to the 'RT Ultra' mode. The demands on hardware, according to Nvidia, are also extreme, at 635 rays per pixel.

Game developers have tried to square this circle by implementing ray tracing in increasingly efficient ways. One good example is AI upscaling techniques like NVIDIA's Deep Learning Super Sampling (DLSS) or AMD's FidelityFX Super Resolution (FSR). Both of these technologies allow games to be rendered at a lower internal resolution, then intelligently upscale footage boosting performance without sacrificing picture quality.

For instance, the September 2023 *Cyberpunk 2077* 2.0 update introduced support for DLSS 3.5, which includes Ray Reconstruction. This improves the game's frame rate, provides superior image quality, and reduces VRAM usage provided the player has a compatible NVIDIA RTX 40 series GPU.

Looking to the future, it's very likely that ray tracing will be embraced more fully by games, but it has other useful applications. For instance, ray tracing can be used in architectural software to generate photorealistic images of videos before they're constructed. This could allow architects and their clients to get a better insight to the look and feel of the structure by taking a virtual tour, then make changes as necessary.

The main challenges that remain for ray tracing are universal adoption, as well as ensuring the feature works consistently across all modern hardware. This will become easier through using better machine learning techniques for denoising and upscaling games and videos.

RACKET TRACING

While ray tracing is most commonly associated with rendering realistic images and videos, its principles can also be applied to sounds. For example, in July 2024, Meta released a new audio ray tracing tool for the Meta Quest.

Ray-traced audio works by casting sound rays from sources, then tracking their paths as they bounce off surfaces. Like light, sound waves will reach the listener in various ways.This can make audio sound more real, as sound can bounce off surfaces to create realistic echoes and reverberations that match the virtual environment.

Games like *Avatar: Frontiers of Pandora* deploy the Snowdrop engine to allow dynamic occlusion. This determines how sound is perceived if there's an object in the way, such as when the player steps behind a tree when near a waterfall. Sound can also travel around or through objects in different ways—in the above example, a tree would obstruct sounds far more than a bush, which contains more gaps.

In the case of *Frontiers of Pandora*, this attempt at realism initially backfired. In an interview with Massive Entertainment, audio director Alex Riviere admitted that the combined sounds of nature would have "overwhelmed" new players. While any reader who has spent time in a real jungle will know that background noise truly can reach cacophonic levels, the developers toned it down to allow players to focus.

Another advantage of implementing sound using ray tracing is that audio can be managed by the GPU, leaving the CPU free to manage other aspects of gameplay.

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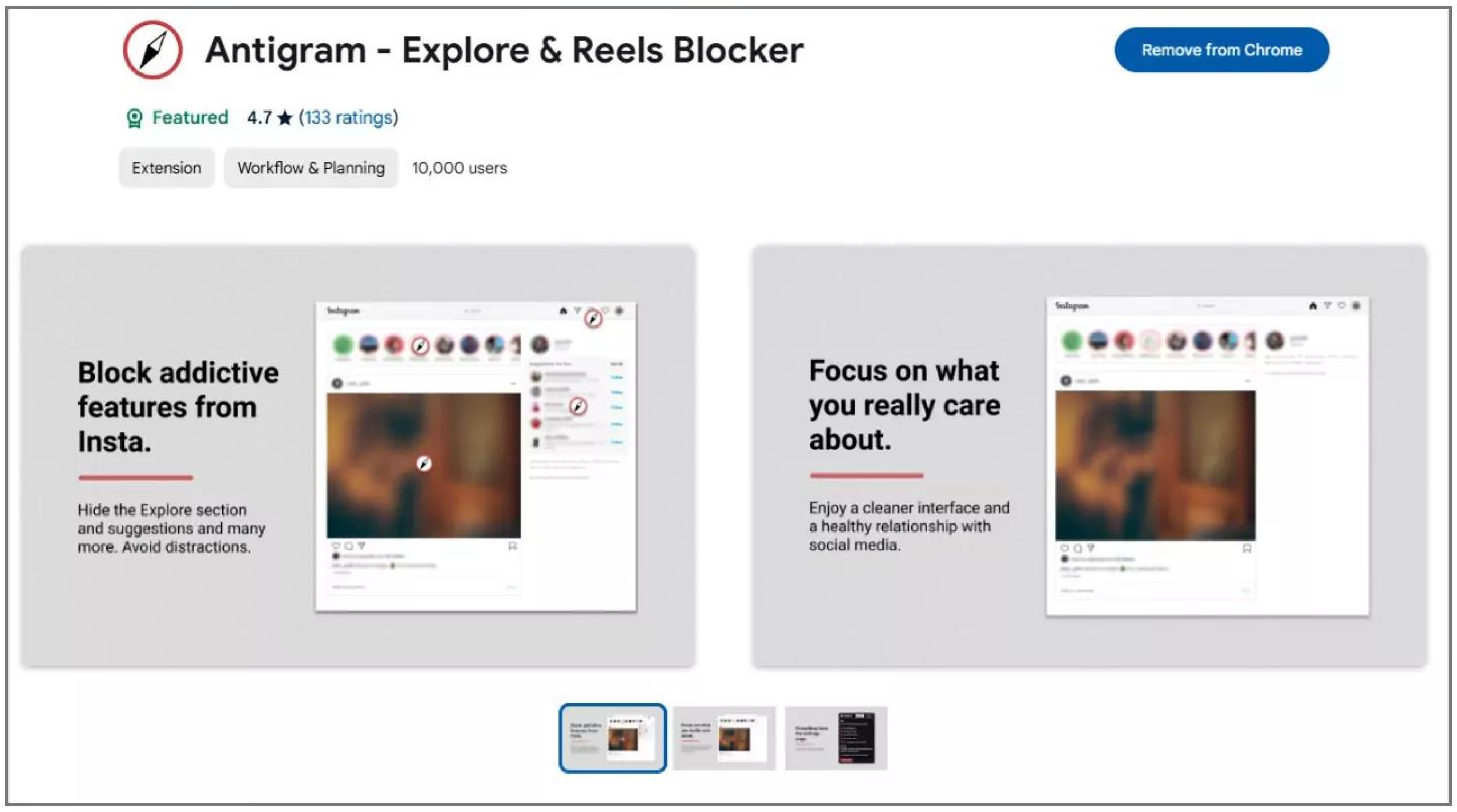
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



Antigram - Explore & Reels Blocker

Remove from Chrome

Featured 4.7 ★ (133 ratings)

Extension | Workflow & Planning | 10,000 users

Block addictive features from Insta.

Hide the Explore section and suggestions and many more. Avoid distractions.

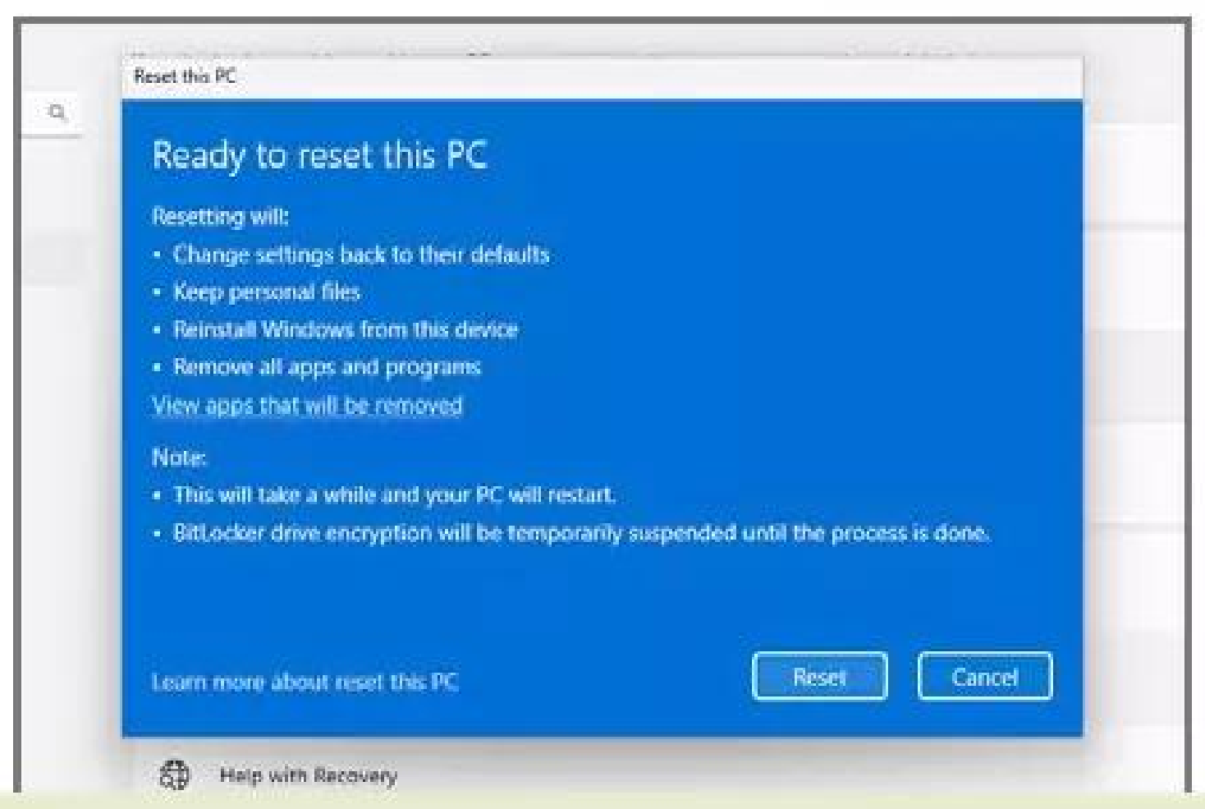
Focus on what you really care about.

Enjoy a cleaner interface and a healthy relationship with social media.

ANTIGRAM - BLOCK INSTAGRAM REELS

Fed up of getting stuck watching pointless Instagram reels in your spare time? Want to feel slightly more productive on your PC? Perhaps it's time to kick those dopamine hits in the backside, and block them entirely. Google Chrome's Antigram extension does just that. Block the Explore, Stories, and Reels section, and automatically default to a list of posts from the people you follow. It's like social media from 2011 again.

MAKE – USE – CREATE



Reset this PC

Ready to reset this PC

Resetting will:
- Change settings back to their defaults
- Keep personal files
- Reinstall Windows from this device
- Remove all apps and programs

View apps that will be removed

Note:
- This will take a while and your PC will restart.
- BitLocker drive encryption will be temporarily suspended until the process is done.

Learn more about reset this PC

Reset | Cancel

Help with Recovery

60
Remove bloatware from Windows

```
DOSBox 0.74-3, Cpu speed:    3000 cycles, Frameskip  0, Program:  DOSBOX

Welcome to DOSBox v0.74-3

For a short introduction for new users type: INTRO
For supported shell commands type: HELP

To adjust the emulated CPU speed, use ctrl-F11 and ctrl-F12.
To activate the keymapper ctrl-F1.
For more information read the README file in the DOSBox directory.

HAVE FUN!
The DOSBox Team http://www.dosbox.com
Z:\>SET BLASTER=A220 I7 D1 H5 T6

Z:\>mount c /home/nate/DOS-GAMES
Drive C is mounted as local directory /home/nate/DOS-GAMES/

Z:\>C:

C:\>CD ABUSE_
```

64
Play Windows games on Linux

68
Use Windows Mobile Hotspot

© GOOGLE CHROME, MICROSOFT, DOSBOX, TP-LINK

ZAK STOREY
CONTRIBUTOR

SCREWING UP

I was at my second job, opening up the coffee shop with my other boss (sorry Guy), and we got talking about screws.

Tom, the head chef/owner, had been taking apart a mountain bike, and struggled to get a screw off because he didn't have the right bit. Nico, one of our kitchen staff, said how much he hated the random sizes and heads he had to deal with on his car, and asked how much I hated them in PCs.

The irony was I'd had that exact thought while building this issue's cover PC. I can understand having different heads in other fields, but for me, it's the thread size. To be clear, we have four screws in PC building: the big bulky self-tapping fan screw, the power supply screw, and two that look almost the same shape and size, but with slightly different threads.

Why is it that after 22 years of PC building, the industry hasn't settled on one size and thread for every component outside of a fan? Why do we need so many? Again, fan screws, radiator screws, sure. But the amount of times I've grabbed a screw that's slightly too small for a motherboard standoff, installed it, then watched it fall out five seconds later, is countless. Yes, it's a first-world problem, but it's still a major frustration.

I never thought I'd write this column, but sometimes you need to speak truth to power.

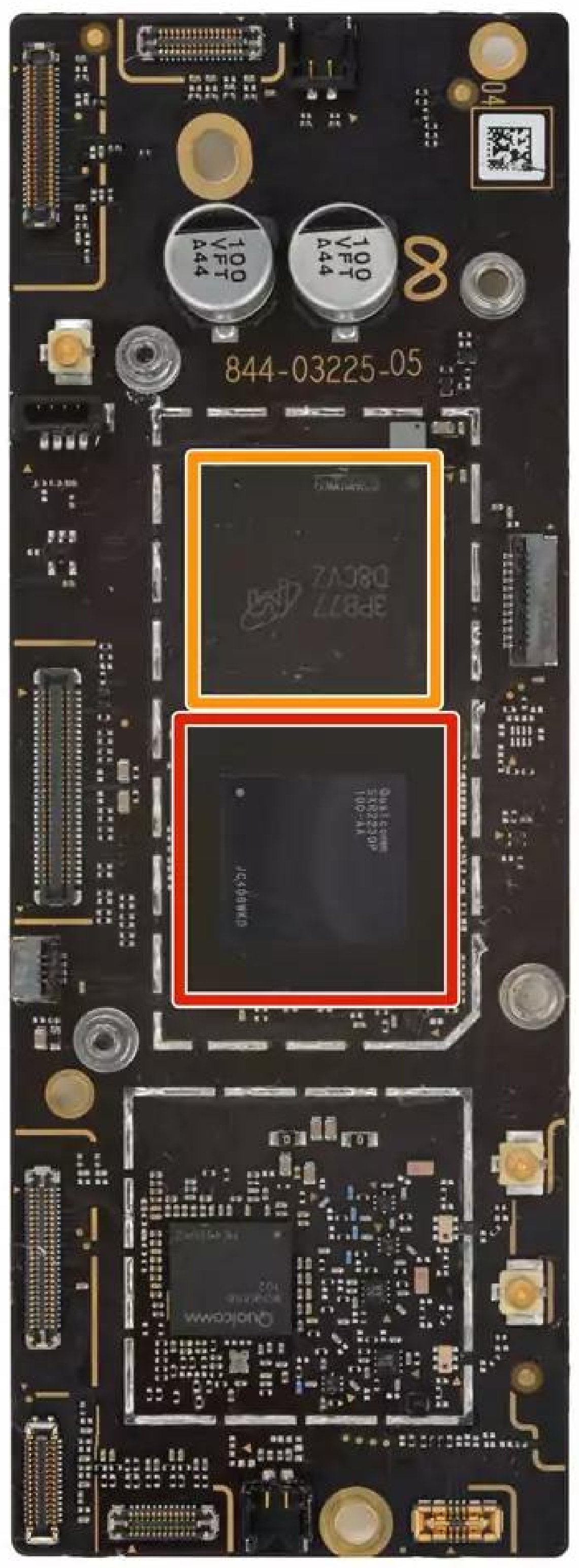
↘ submit your How To project idea to: editor@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

Meta Quest 3S



The Qualcomm Snapdragon XR2 Gen 2 SoC is the one major spec item that's shared with the Quest 3.

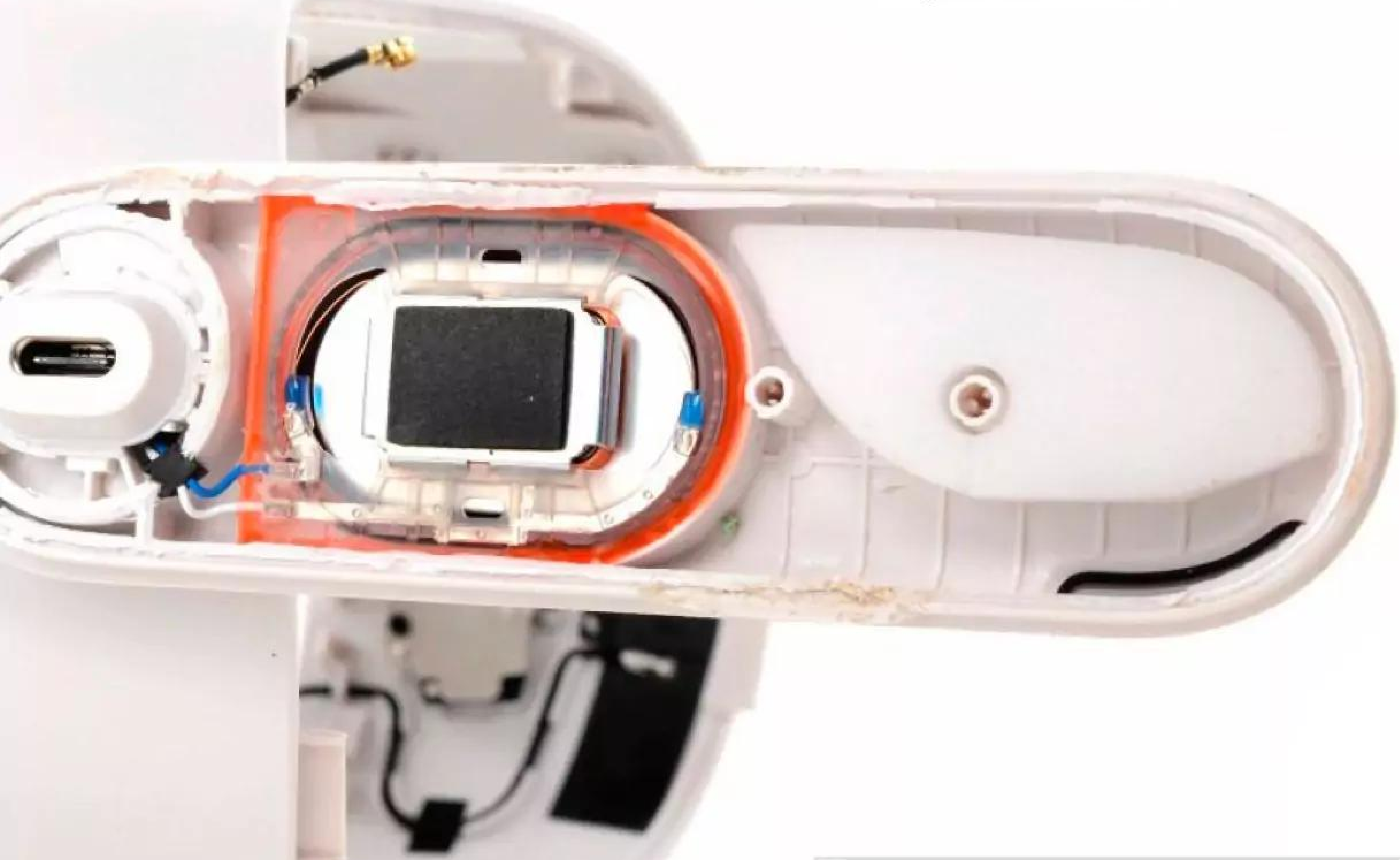
About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com

The same fresnel lenses are a dead giveaway that the Quest 3S is actually more closely related to the Quest 2 than the Quest 3.

Because the Quest 3S and Quest 2 share some critical components, we have the ability to salvage broken old Quest 2s and repurpose parts.

The speaker arms borrow their design from the Quest 3, with the speaker located across the central length of the arm.



The 3S sports dual RGB passthrough cameras, four integrated cameras, and two IR flood illuminators, but no proximity sensor.

The battery housing retains the same design as before, but the battery connector itself has changed as a result of losing that proximity sensor.

BACKGROUND

The Quest 3S is not a budget version of the Quest 3. Yes, it has the Quest 3's redesigned speaker arms, color passthrough, and the Snapdragon XR2 Gen2 SoC. But the 3S is really a true successor to 2020's Quest 2.

MAJOR TECH SPECS

- 120Hz LCD display, 1,832 by 1,920 resolution per eye
- Fresnel lenses, 97 degree horizontal field of view, 20 pixels per degree
- Qualcomm Snapdragon XR2 Gen 2 SoC, Octa-core Kryo CPU (1 x 3.19 GHz, 4 x 2.8 GHz, 3 x 2.0 GHz)
- Dual RGB passthrough cameras, 58-68mm IPD range (manually hardware adjustable, 3 fixed IPD settings), 6 DoF Inside-out via 4 integrated cameras
- 8GB RAM, 128GB storage (256GB optional)
- 2x Meta Quest Touch Plus Controllers, capacitive face buttons, capacitive joystick, capacitive touch pad, capacitive index trigger, middle finger triggers
- WiFi 6E, Bluetooth, USB-C

KEY FINDINGS

- The most obvious difference between the Quest 3 and Quest 3S is in the optical stack. Meta saved themselves some local processing power by opting for the bulkier but cheaper-to-implement Fresnel lenses, just like the ones in the Quest 2. No, 'just like' isn't right. They *are* the ones used in the Quest 2. These parts are 100 percent compatible with each other.

- If we make our way past the optical stack and to the screen, we'll find the same LCD panel being used too. This is the same RGB stripe LCD panel that the Quest 2 uses, right down to the display panel connector.

- The most important change is the spec bump from the 7nm Qualcomm Snapdragon XR2 Gen1 SoC with 6GB of RAM to the 4nm Gen2 SoC with 8GB of RAM. This is the main similarity between the Quest 3 and Quest 3S. With it is a wireless IC upgrade, bringing WiFi 6E and BT 5.2 support.

- The battery housing retains the same design, but the connector has changed as a result of losing the proximity sensor. Without this, the Quest 3S appears to be on a timed auto-shutoff, which is a reduction in complexity, and an easy way to solve what was a nasty problem.

- The speaker arms have also borrowed their design from the Quest 3, with the circular speaker-as-a-fulcrum design from the Quest 2 swapped for a speaker across the central length of the arm. This should improve audio quality when compared to the Quest 2. Unfortunately, somebody at Meta forgot to include the headphone jack during this transition. Of all the places a headphone jack would be most appreciated, surely immersive gameplay would be one?

- In another design departure, a rare iterative improvement over the Quest 3, the depth sensor has been swapped for two IR flood illuminators. The sensor suite has been redesigned to give it a sharp and somewhat arachnid aesthetic. Each cluster of sensors consists of one of the aforementioned IR illuminators, an RGB passthrough camera, and a tracking camera, with two sensors mounted under the device, pointing down for body, hand, and controller tracking.

- Repairability Score: 6 out of 10 (10 is easiest to repair). Because the Quest 2 and Quest 3S share some critical components, we have the ability to salvage broken Quest 2s. This helps reduce the carbon footprint of both devices by allowing an avenue for the reuse of components in this next generation. This shows why it can be so beneficial to lean into existing technologies and manufacturing processes.

Remove bloatware from Windows

YOU'LL NEED THIS

CCLEANER
Optional—download it from
www.ccleaner.com

A STABLE INTERNET CONNECTION

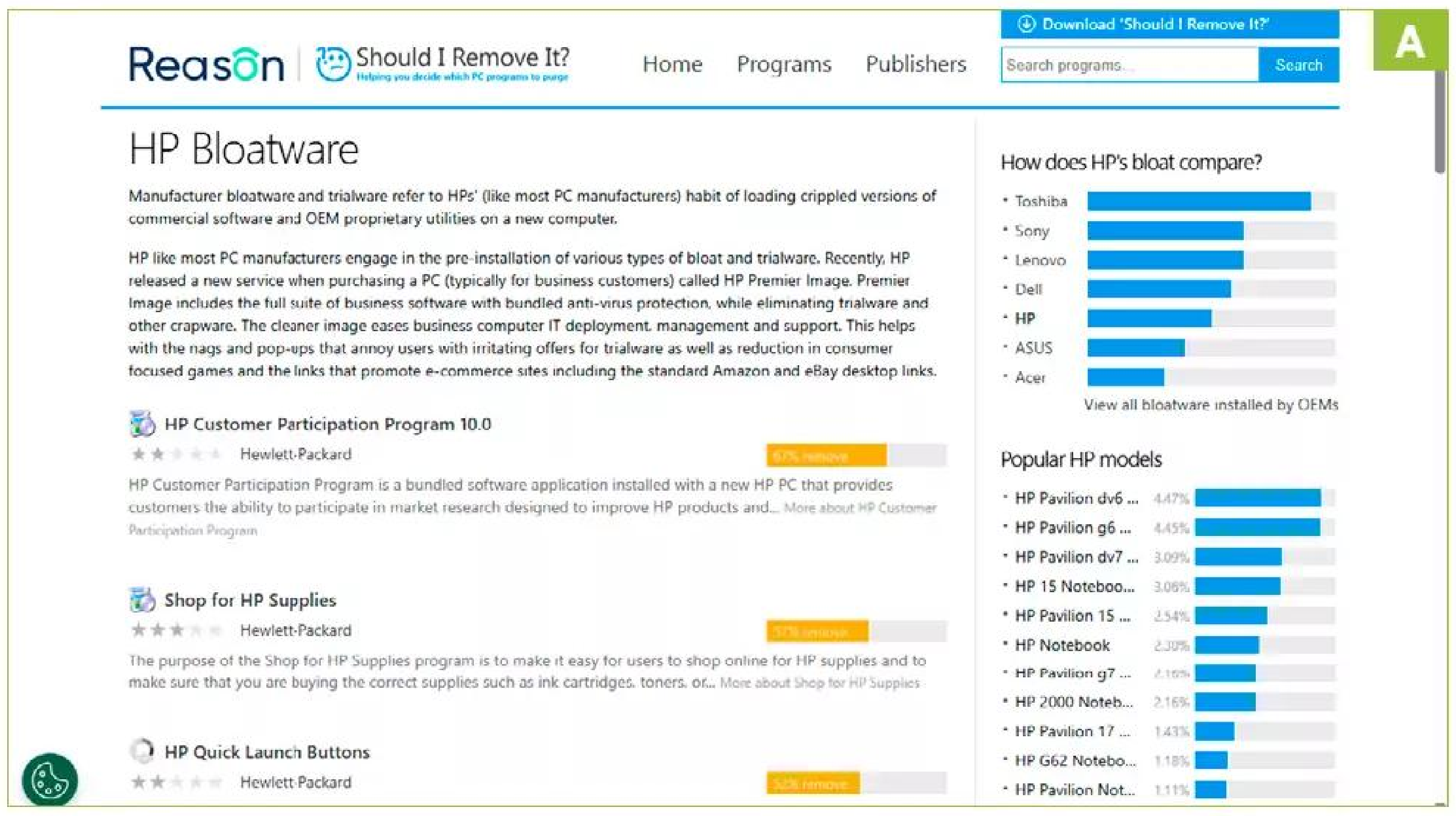
MAXIMUM PC READERS will know that nothing quite compares to the glee of firing up a brand new laptop or computer for the first time. Unfortunately, your excitement can easily be dampened by the presence of 'bloatware'. This is software that usually comes bundled with Windows, and provides no significant value to the user.

Common culprits included third-party antivirus and media software. As Windows veterans know, these programs may offer a free trial, and even work unobtrusively for a short period of time. However, at the end of the trial period, users are usually plagued with pop-ups encouraging them to register and/or subscribe.

Bloatware, by definition, is software that is unnecessary to the smooth running of the OS. The more bloatware you have, the greater the drain on your system resources, particularly during startup. Unnecessary programs are also an extra drain on the battery of portable devices.

Even if you have a PC with plenty of RAM and storage to spare, having unknown programs on your machine is a bad idea. Bloatware can interfere with the running of legitimate Windows software. Given that most bloatware is proprietary, there may also be security bugs.

In this guide, we'll explore ways both to reduce your attack surface and free up resources by identifying, then removing, bloatware from your device. –**NATE DRAKE**


A
Reason | Should I Remove It?
Helping you decide which PC programs to purge
Home
Programs
Publishers
Download 'Should I Remove It?'
Search programs...
Search

HP Bloatware

Manufacturer bloatware and trialware refer to HPs' (like most PC manufacturers) habit of loading crippled versions of commercial software and OEM proprietary utilities on a new computer.

HP like most PC manufacturers engage in the pre-installation of various types of bloat and trialware. Recently, HP released a new service when purchasing a PC (typically for business customers) called HP Premier Image. Premier Image includes the full suite of business software with bundled anti-virus protection, while eliminating trialware and other crapware. The cleaner image eases business computer IT deployment, management and support. This helps with the nags and pop-ups that annoy users with irritating offers for trialware as well as reduction in consumer focused games and the links that promote e-commerce sites including the standard Amazon and eBay desktop links.

HP Customer Participation Program 10.0
Hewlett-Packard
HP Customer Participation Program is a bundled software application installed with a new HP PC that provides customers the ability to participate in market research designed to improve HP products and... More about HP Customer Participation Program

Shop for HP Supplies
Hewlett-Packard
The purpose of the Shop for HP Supplies program is to make it easy for users to shop online for HP supplies and to make sure that you are buying the correct supplies such as ink cartridges, toners, or... More about Shop for HP Supplies

HP Quick Launch Buttons
Hewlett-Packard

1 IDENTIFY BLOATWARE

Bloatware is a many-headed beast. One of the most common forms is 'junkware'—software for activities like listening to music or to forecast the weather. There are usually better ways to do this using Windows' built-in features or free and open-source alternatives.

» Trialware is also a form of bloatware. This includes software like antivirus programs, which functions well enough for a set time. However, at the end of the trial, these forms of bloatware tend to aggressively remind the user to purchase a subscription to continue to benefit from its features.

» Some bloatware, like adware, is much more blatant, displaying pop-ups for a particular product or service, even when you're using legitimate programs, like your web browser.

» Unnecessary toolbars and browser extensions can also be bloatware. They can slow down your connection and even present security risks if they share your data without your consent.

» Readers will note that we haven't written out a grocery list of apps to remove from your Windows PC. This is because bloatware is defined by its behavior. The closest you can get are websites like 'Should I Remove It?' (www.shouldiremoveit.com), which list common applications that people remove [**Image A**].

» For instance, upon visiting the 'Programs' section of the site, we discovered that 29 percent of polled users removed 'HP Update'. This is a legitimate program for checking and downloading updates, and comes preinstalled on many HP machines. While it's clearly convenient, you can always remove and run updates manually.

» The website also has dedicated sections listing common bloatware for certain types of machines. The HP section, for example, lists programs like 'HP Customer Participation'.

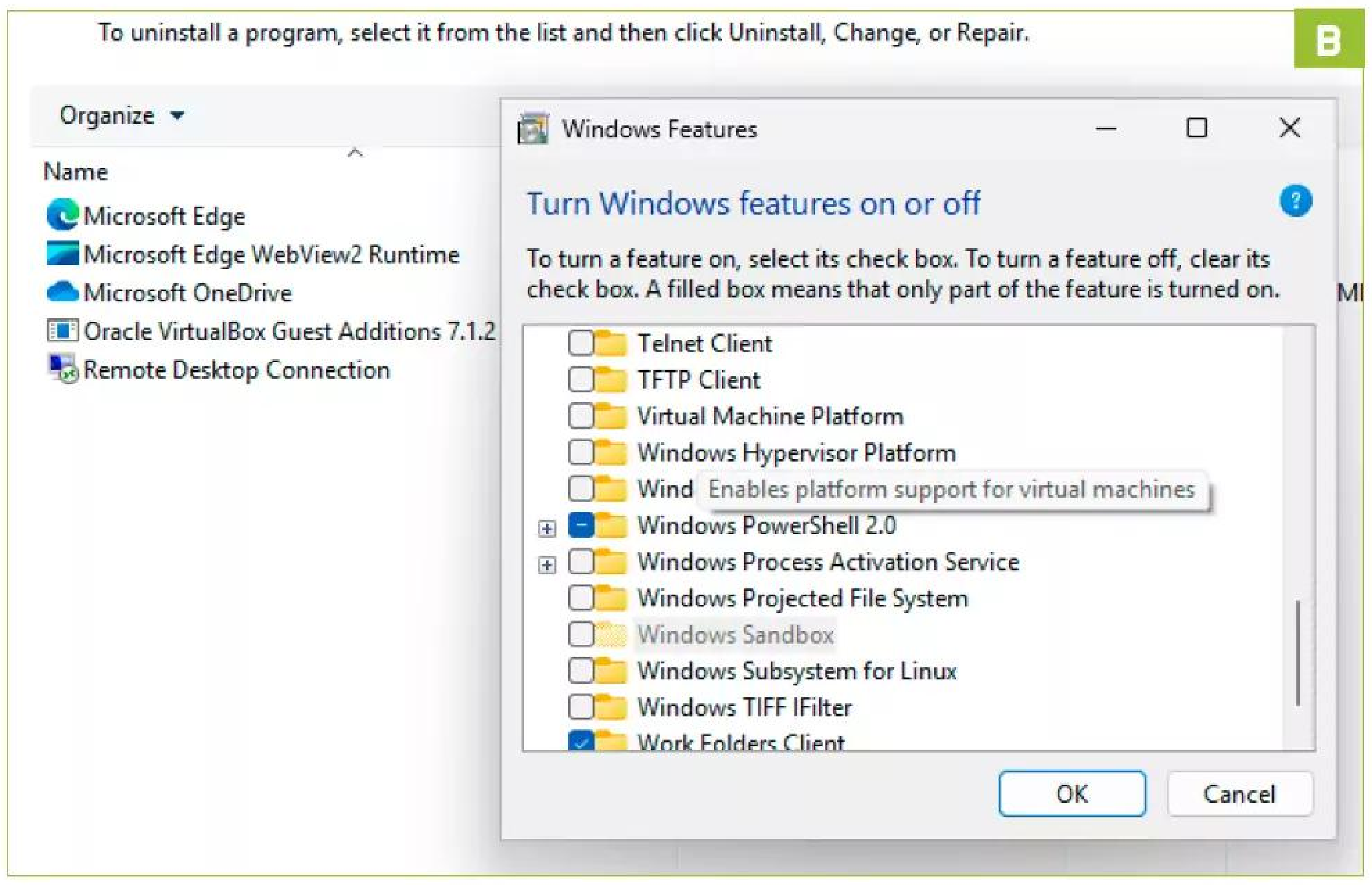
» We recommend running a full system backup before proceeding with the following steps, just in case you accidentally remove any important software.

2 REMOVE PROGRAMS VIA SETTINGS

To see which programs you currently have installed, enter 'programs' into the Windows search bar to launch 'Add or remove programs'.

» Take the time to scroll through this list and compare the listed apps with a reputable database such as "Should I Remove It?"

» This is a worthwhile activity, even if you performed a clean install of Windows 11 yourself, as there are a number of Microsoft apps that you may not use. In


B
Organize
Name
Microsoft Edge
Microsoft Edge WebView2 Runtime
Microsoft OneDrive
Oracle VirtualBox Guest Additions 7.1.2
Remote Desktop Connection
Windows Features
OK
Cancel

To uninstall a program, select it from the list and then click Uninstall, Change, or Repair.

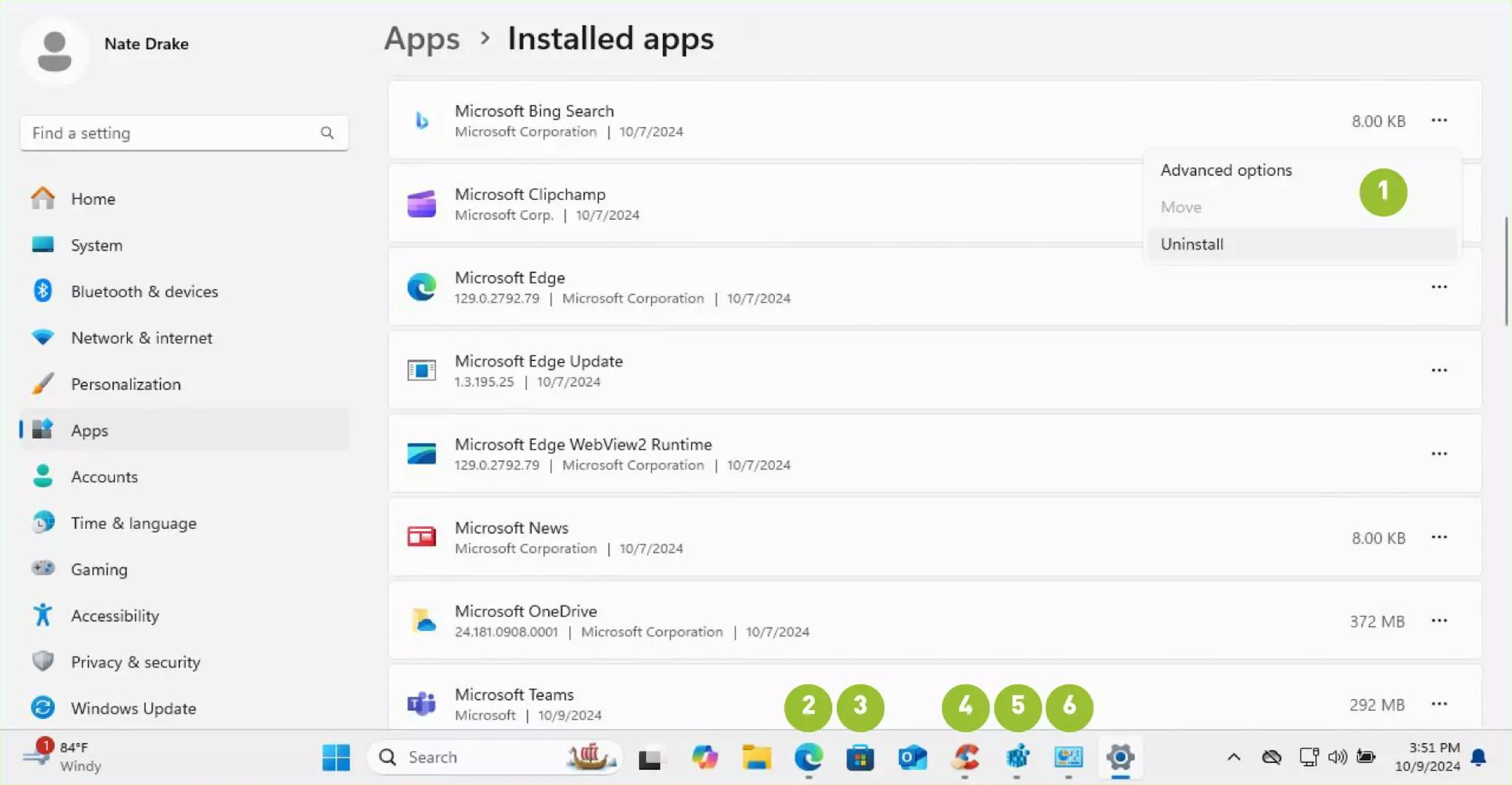
Turn Windows features on or off

To turn a feature on, select its check box. To turn a feature off, clear its check box. A filled box means that only part of the feature is turned on.

☐ Telnet Client
☐ TFTP Client
☐ Virtual Machine Platform
☐ Windows Hypervisor Platform
☐ Wind Enables platform support for virtual machines
■ Windows PowerShell 2.0
☐ Windows Process Activation Service
☐ Windows Projected File System
☐ Windows Sandbox
☐ Windows Subsystem for Linux
☐ Windows TIFF IFilter
☑ Work Folders Client

© SHOULD I REMOVE IT, MICROSOFT

A BLOATWARE-FREE SYSTEM


Nate Drake
Find a setting
Home
System
Bluetooth & devices
Network & internet
Personalization
Apps
Accounts
Time & language
Gaming
Accessibility
Privacy & security
Windows Update
Apps › Installed apps
Microsoft Bing Search
Microsoft Corporation | 10/7/2024
8.00 KB
Advanced options
Move
Uninstall
Microsoft Clipchamp
Microsoft Corp. | 10/7/2024
Microsoft Edge
129.0.2792.79 | Microsoft Corporation | 10/7/2024
Microsoft Edge Update
1.3.195.25 | 10/7/2024
Microsoft Edge WebView2 Runtime
129.0.2792.79 | Microsoft Corporation | 10/7/2024
Microsoft News
Microsoft Corporation | 10/7/2024
8.00 KB
Microsoft OneDrive
24.181.0908.0001 | Microsoft Corporation | 10/7/2024
372 MB
Microsoft Teams
Microsoft | 10/9/2024
292 MB
1
2
3
4
5
6
84°F
Windy
Search
3:51 PM
10/9/2024

1. APP SETTINGS
Most applications can be removed via Windows settings, unless they form a core part of the operating system, like Edge. Some Microsoft programs, like Clipchamp, can be uninstalled here.

2. BROWSER BLOATWARE
Web browsers don't often come with bloatware, but users can sometimes install redundant extensions, like multiple adblockers. Edge also collects data to make personalized suggestions, though you can disable this.

3. MICROSOFT STORE
Although you can no longer remove applications from here, Windows can be configured only to allow installation of software from the Microsoft Store. This reduces the chance of accidentally installing bloatware.

4. CCLEANER
This useful (and free) utility has multiple features for removing bloatware. These include deleting a broader range of Microsoft apps, as well as scanning the registry for obsolete software entries.

5. REGISTRY EDITOR
An important tool in beating bloatware, the Registry can hide entries for startup apps not listed in Windows settings. Check settings for your account and the 'Local Machine' for these.

6. CONTROL PANEL
This has a function for removing third-party programs. You can also view and disable Windows features like VMP to improve system performance.

the case of our virtual machine, for instance, we successfully removed both Microsoft Bing Search and Microsoft News.

» You can also uninstall Microsoft 'Quick Assist' and 'Remote Desktop Connection' safely, provided that you don't need to use the screen-sharing feature.

» In each case, removing an app is as simple as clicking the ... next to the program name, then choosing 'uninstall'. If you think you may need to use a feature like 'Quick Assist' in the future, instead of uninstalling, choose 'Advanced options'.

» In the 'Background app permissions' section, change the drop-down menu to 'Never'. Next, scroll down and click 'Terminate' to end the current process. Moving forward, the program won't consume any system resources unless you enable it manually, or if it's configured to launch upon startup.

» Once you've worked through the list of programs, click into the 'Apps' category at the top of the screen, and choose 'Advanced app settings'.

» By default, the drop-down for 'Choose where to get apps' is set to 'Anywhere'. As an experienced user, you'll probably want to leave this as it is. However, if you're following this tutorial to clear bloatware from a friend or family member's PC, change this to 'The Microsoft store only'. This means there's less chance that your loved one will install junkware directly from the internet in future.

» Next, double-check that 'Archive apps' is enabled. This very useful Windows feature ensures that apps you don't use regularly are archived to save both space and bandwidth. If you do choose to launch an archived app, the full version will automatically be restored, along with any user data.

3 CONTROL AND CLEAN

Although Windows Settings offers an easy way to view and remove installed apps, you can also do so via the Control Panel [Image B]. This is a good way to examine legacy programs.

» To get started, launch the Control Panel and choose 'Uninstall a program'. Right-click an app to 'Uninstall'. As with Windows' app settings, you cannot remove any applications like Edge, which form a core part of the OS.

» Once you've removed any unneeded apps, select 'Turn Windows features on or off'. These aren't

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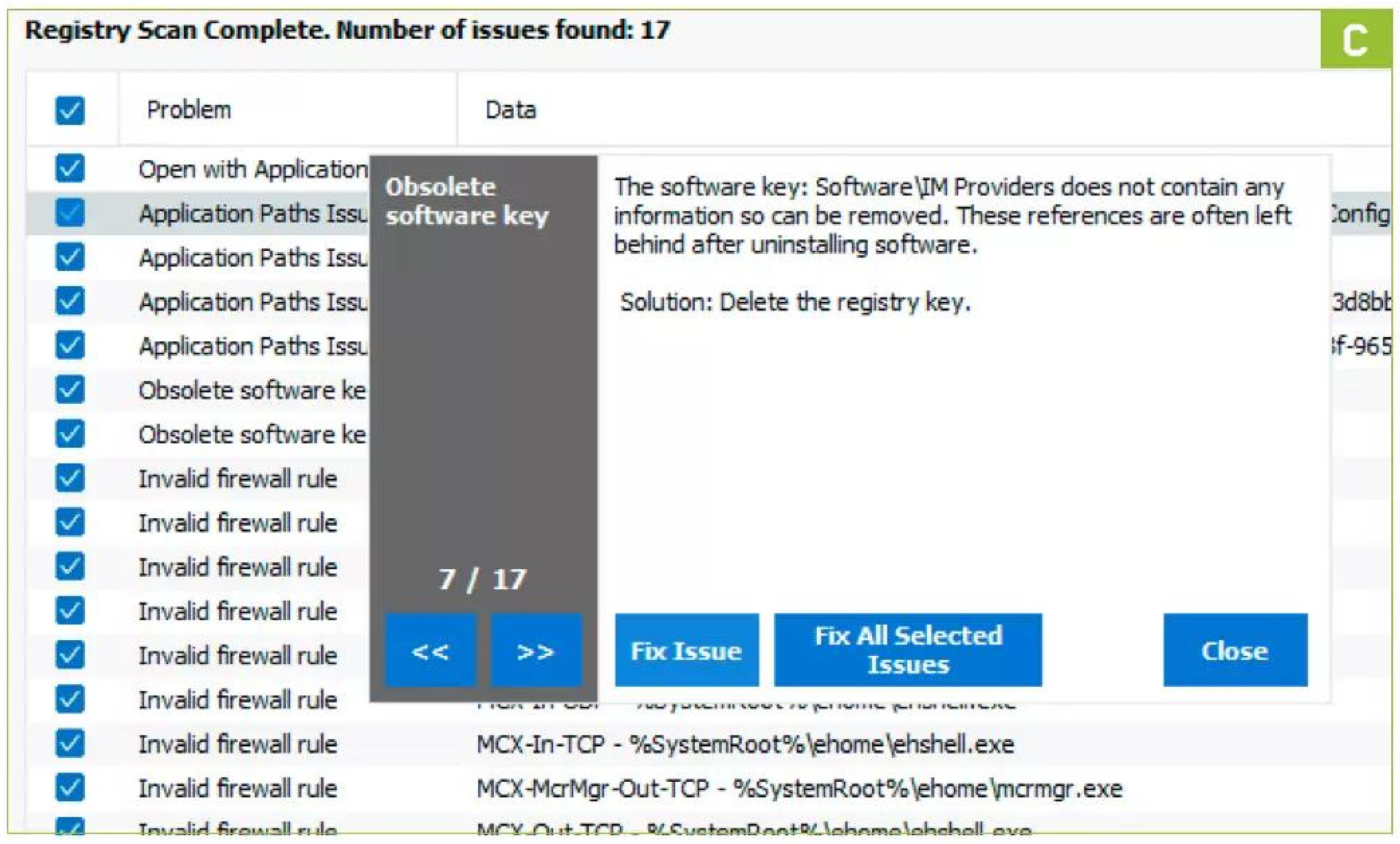


C

Registry Scan Complete. Number of issues found: 17

☑	Problem	Data
☑	Open with Application	
☑	Application Paths Issu	:onfig
☑	Application Paths Issu	
☑	Application Paths Issu	3d8bb
☑	Application Paths Issu	f-965
☑	Obsolete software ke	
☑	Obsolete software ke	
☑	Invalid firewall rule	
☑	Invalid firewall rule	
☑	Invalid firewall rule	
☑	Invalid firewall rule	
☑	Invalid firewall rule	
☑	Invalid firewall rule	
☑	Invalid firewall rule	MCX-In-TCP - %SystemRoot%\ehome\ehshell.exe
☑	Invalid firewall rule	MCX-McrMgr-Out-TCP - %SystemRoot%\ehome\mcrmgr.exe

Obsolete software key

The software key: Software\IM Providers does not contain any information so can be removed. These references are often left behind after uninstalling software.

Solution: Delete the registry key.

bloatware, but disabling unnecessary features can improve system performance.

» For example, VMP (Virtual Machine Platform) provides core virtual machine services in Windows. According to Microsoft's support documentation, this can impact gaming performance. Disable features by unchecking the corresponding tick box. Once this is done, restart your device to implement the changes.

» If you're having trouble uninstalling a third-party app via either Windows Settings or Control Panel, open the Microsoft Store, and install CCleaner.

» This utility is not bloatware—it can be used to remove leftover files and registry entries when the usual uninstall methods don't work. Upon launch, choose to 'Run your first scan'. Save and close any running programs so they can be scanned as well.

» Once the scan is complete, choose 'Tools' from the left-hand pane, then 'Uninstall' at the top left. CCleaner will now list any remaining programs.

» One major advantage of using CCleaner is that it has a more flexible approach to the programs it can delete. For instance, although App settings doesn't allow you to remove Windows programs, we were able to remove the system calculator and Xbox Game Bar using the utility.

» There are two options for app removal. The first ('Uninstall') will simply run the program's own uninstaller.

» You can also choose 'Delete'. This removes the uninstall entry without deleting the program. This is useful when an application has been uninstalled, but is still listed in App Settings.

4

POWERING UP

Back in Step 1, we admitted that we didn't have a 'grocery list' of bloatware that users should uninstall.

» We've left this to others like developer Raphire, the creator of 'Win11Debloat'. This PowerShell script is designed to remove preinstalled Windows bloatware apps like Microsoft Journal. It also can remove certain third-party programs, like 'WinZipUniversal'.

» You can view the full list of supposed bloatware apps and the Win11Debloat script itself from https://github.com/Raphire/Win11Debloat.

» The quickest way to get started is to enter 'powershell' into the Windows search bar, then right-click to 'Run as administrator'.

» Next, enter the following command to download and launch the script:

```
& ([scriptblock]::Create((irm “https://win11debloat.
raphi.re/”)))
```

» The utility will be downloaded, then launch in another window. The main menu lists three options. Choose '2' to customize the script to your needs.

» From here, you can just choose to remove the default selection of apps listed on the Github page (option 1). Win11Debloat can also remove other programs, like calendar and developer apps (option 2).

» If you prefer to have some say in what's removed, choose option 3. This will launch a pop-up window where you can check apps to remove. Read through the list carefully, as not all of these are bloatware. For instance, Plex media server and Netflix are listed.

» If you click 'Confirm' to remove any programs, the utility will also ask if you wish to remove the corresponding pinned app from the Start Menu.

» Win11DeBloat also asks if you want to disable telemetry, diagnostic data, activity history, app-launch tracking, and targeted ads.

» You can also take the same for suggestions and ads in the Start Menu, as well as the file explorer and lockscreen. The utility also supports removing Bing and Copilot.

» Make your choices, then press enter to execute.

TINY VICTORIES

If you've followed this guide, you'll see that when it comes to bloatware, Microsoft itself is one of the main culprits.

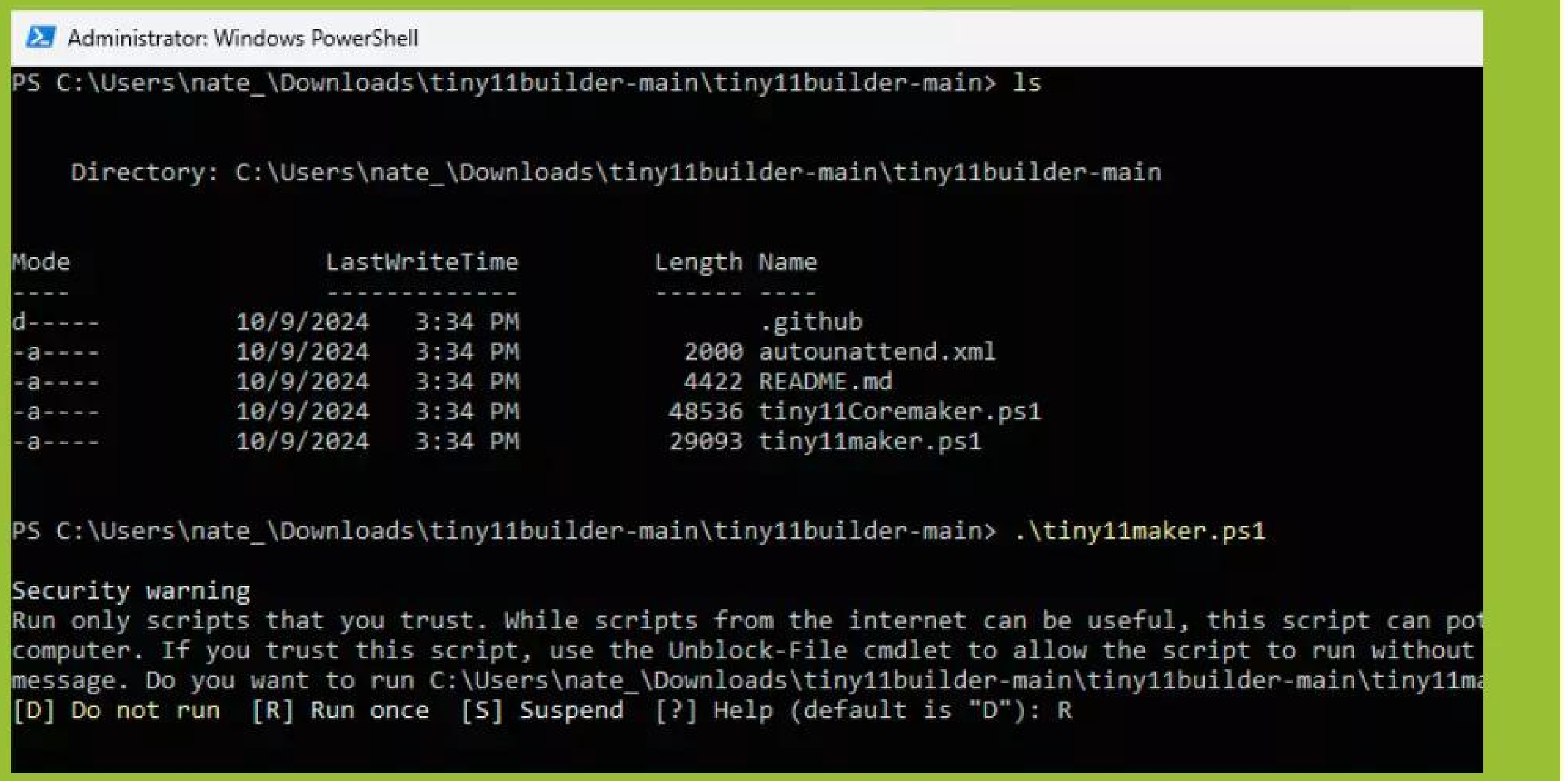
The development team at NTDEV have offered a solution: Tiny11, a stripped-down version of Windows 11. Its main purpose is to offer a less resource-hungry OS—the install footprint is only 8GB, compared to around 20GB for stock Windows.

However, as the developer page for their custom script (https://github.com/ntdevlabs/tiny11builder) states, Tiny11 also eliminates most bloatware, like Clipchamp and Weather.

Tiny11 ISOs are available from sites like the Internet Archive. The developers recommend using the 'tiny11builder' PowerShell script on a recent version of Windows for an up-to-date custom ISO.

Download a recent version of Windows 11 from the Microsoft site. Next, right-click the ISO, and choose to 'Mount' in Windows Explorer.

Open PowerShell as Administrator and ensure



```
PS C:\Users\nate_\Downloads\tiny11builder-main\tiny11builder-main> ls


    Directory: C:\Users\nate_\Downloads\tiny11builder-main\tiny11builder-main


Mode                 LastWriteTime         Length Name
----                 -------------         ------ ----
d-----         10/9/2024   3:34 PM                .github
-a----         10/9/2024   3:34 PM           2000 autounattend.xml
-a----         10/9/2024   3:34 PM           4422 README.md
-a----         10/9/2024   3:34 PM          48536 tiny11Coremaker.ps1
-a----         10/9/2024   3:34 PM          29093 tiny11maker.ps1


PS C:\Users\nate_\Downloads\tiny11builder-main\tiny11builder-main> .\tiny11maker.ps1

Security warning
Run only scripts that you trust. While scripts from the internet can be useful, this script can pot
computer. If you trust this script, use the Unblock-File cmdlet to allow the script to run without
message. Do you want to run C:\Users\nate_\Downloads\tiny11builder-main\tiny11builder-main\tiny11ma
[D] Do not run  [R] Run once  [S] Suspend  [?] Help (default is "D"): R
```

you can run the script with:

```
Set-ExecutionPolicy
unrestricted
```

Download the Tiny11 builder files from the link above, and use 'cd' to change to the folder location. You can execute the .ps1 file with:

```
.\tiny11maker.ps1
```

Enter the drive letter of the Windows 11 ISO you mounted earlier to proceed.

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5

MANAGE STARTUP PROGRAMS

Generally speaking, uninstalling a program will prevent it from loading on your device again. However, more insidious forms of bloatware might propagate themselves across your machine, reinstalling themselves the next time you reboot.

» The easiest way to list programs that launch on login is to enter 'startup' into the search bar to open 'Startup Apps'.

» From here, you can work through the listed applications, then select the rocker switch next to each one as you see fit. Remember, this setting only governs whether a program launches or not. If you want to remove an application, repeat the steps outlined above.

» Certain types of bloatware, like adware, may place an entry in the Windows Registry. This ensures that the application can restart, even if it's disabled in App Settings [**Image C**].

» To fix this, save and close any open files, then launch 'System Configuration' via the Windows search bar. In the 'Boot' tab, check 'Safe boot', then choose 'Apply'.

» You can now restart your device in safe mode. This means that if there are any third-party programs capable of downloading/reinstalling bloatware, they won't launch for this session.

» Once you're in the safe mode desktop, enter 'regedit' into the search bar to launch the Registry Editor.

» Bloatware may be installed for a particular user, or for anyone using your Windows device. To be on the safe side, check the following four Registry sections:

- HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\Run
- HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\RunOnce
- HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Run
- HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\RunOnce

» If you see any applications you don't recognize and/or don't need, right-click the corresponding 'Name', and delete it.

» If you don't feel comfortable tinkering directly with the Registry, the above-mentioned CCleaner can help.

» Relaunch the utility, then choose 'Tools' > 'Registry'. From here, you can scan for common issues.

» Check the following boxes:

- Applications
- Application Paths
- Installer
- Obsolete Software
- Run at Startup

» Choose 'Scan for Issues' > 'Review selected issues'. You can now remove related registry entries.

6

RESETTING WINDOWS

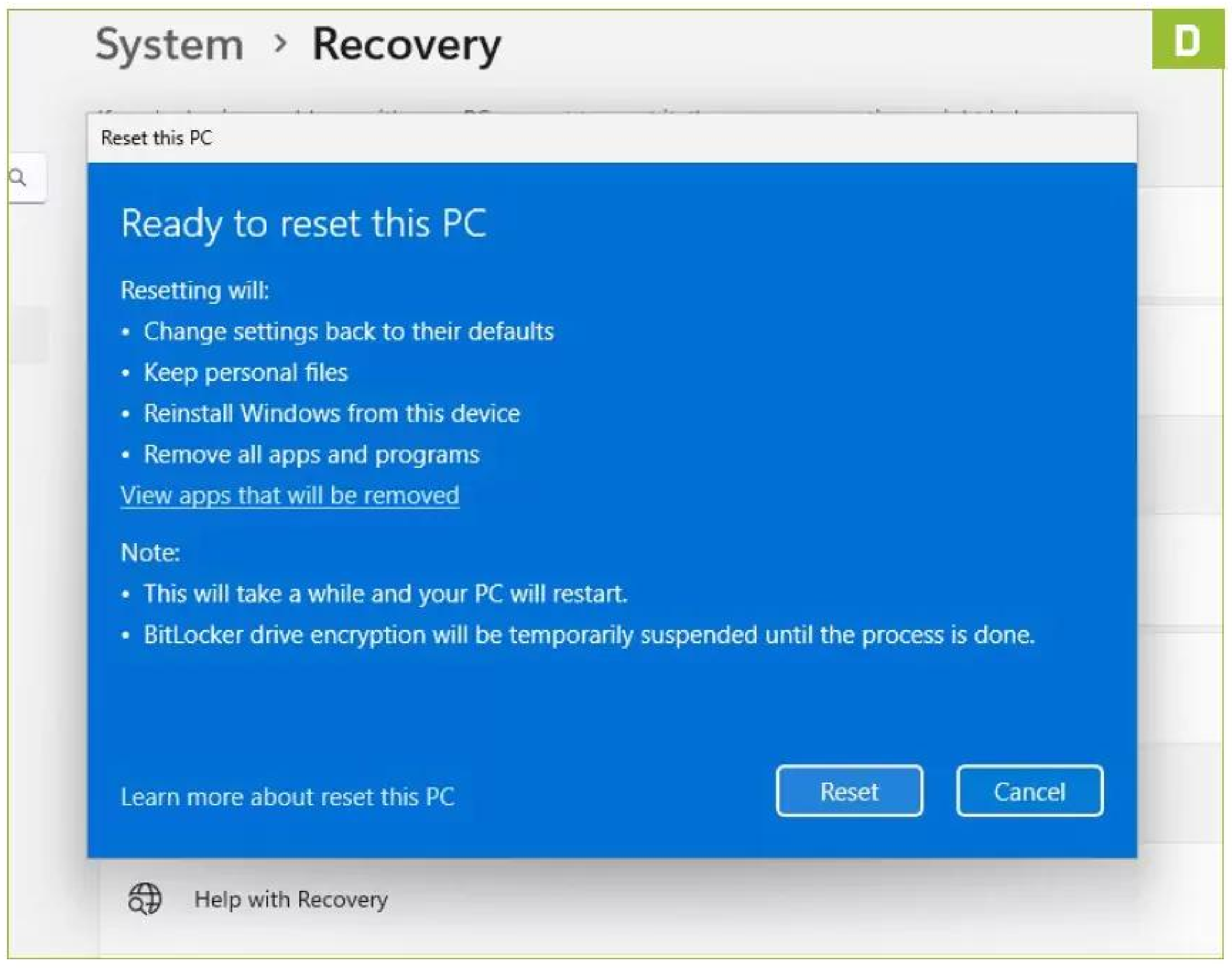
Once you've restarted your device from safe mode ideally no more bloatware will be present and you'll notice a significant increase in system performance.

» If this isn't the case then you can, as Microsoft Support puts it, 'Give your PC a Fresh Start'. This effectively amounts to performing a clean install of Windows 11. You should only proceed once you've made a full backup of all your personal files.

» When this is done, enter 'reset' into the Windows search bar to launch 'Reset This PC'. Under 'Recovery options', choose 'RESET PC' [**Image D**]. You can choose to 'Remove Everything', but the 'Keep my files' options should remove apps and settings without affecting personal files like your Documents folder.

» Choose 'Cloud download' or 'Local reinstall' as you see fit. Click into 'View apps that will be removed', and check it carefully before selecting 'Reset'.

©MICROSOFT



Ready to reset this PC

Resetting will:
- Change settings back to their defaults
- Keep personal files
- Reinstall Windows from this device
- Remove all apps and programs

View apps that will be removed

Note:
- This will take a while and your PC will restart.
- BitLocker drive encryption will be temporarily suspended until the process is done.

Learn more about reset this PC

» Once the reinstall is complete, you may still find programs that you don't want or need. This is because Microsoft bundles applications like Copilot and Xbox Gaming Service, which many people don't use.

» The easiest way to fix this is to repeat the previous steps to download and run Win11DeBloat. However, this time when the utility launches, it's safe just to choose option 1 (Default mode). This will remove the most common types of Microsoft bloatware.

7

BROWSER BLOATWARE

Web browsers can be just as susceptible to bloatware as your operating system. These don't usually come preinstalled, but sometimes, people download extensions they don't need.

» One common culprit is ad blockers, as some web users imagine that having multiple add-ons like these equals better protection. In all likelihood, they will interfere with one another.

» The specific steps to view your currently installed extensions vary by browser. For instance, Chrome and Edge users can select the options button at the top right, then 'Extensions' > 'Manage extensions'.

» Extensions can be disabled temporarily, but if you've no need for them, it's best to just choose 'Remove'.

» Some browsers, like Edge, will also distinguish between add-ons installed from official sources (in this case, the Edge Store) and those from other sources.

» If you're concerned about surfing safely, we recommend installing a single ad blocker (uBlock Origin is an excellent choice), and a single extension for blocking trackers, like Ghostery.

» If you're using Edge, you can also remove some of its less helpful suggestions by going to 'Settings' > 'Privacy, search and services'. Here, you can disable 'Personalization and Advertising'. Scroll to the 'Security' section to disable features like Shopping suggestions.

» We recommend doing the above even if you use a more privacy-focused browser, like Brave or Vivaldi. This is because many Microsoft apps will open web links by default in Edge.

» If you still have CCleaner, launch it and go to 'Tools' > 'Browser Plugins'. You can 'Disable' or 'Delete' extensions configured to launch with your browser.

» If you're not sure if this is safe, choose 'Disable' and use a website like file.net to research the extension. For instance, we discovered the Browser Helper Object ie_to_edge_bho.dll isn't essential.

Play Windows games on Linux

YOU'LL NEED THIS

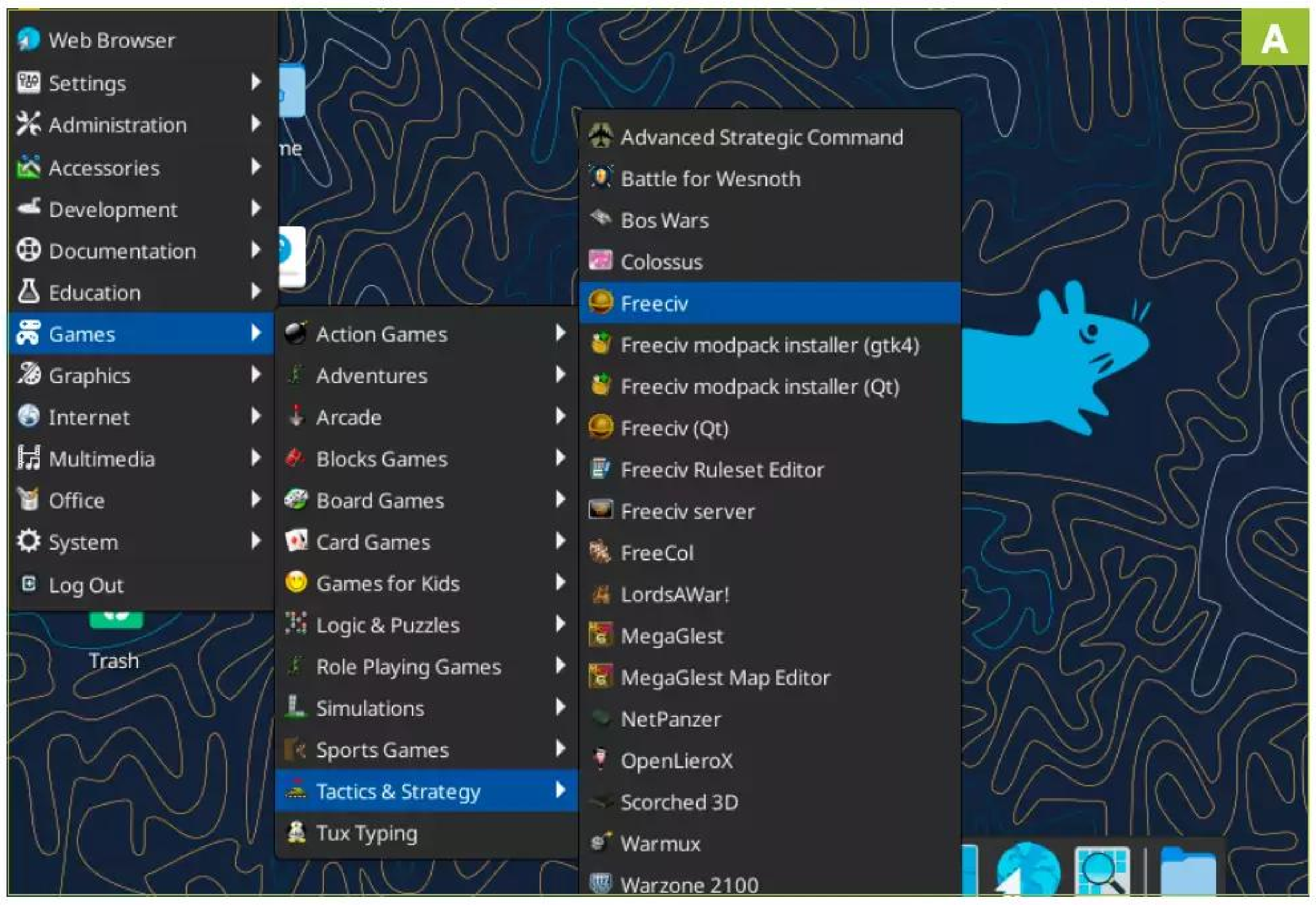
A STABLE INTERNET CONNECTION
For downloading Linux and the games you'll want to play.

MANY WINDOWS PCS could become redundant in October 2025 due to Windows 11's TPM 2.0 requirements. This could result in over 250 million junked devices. This means that there's never been a better time to switch to Linux. Although it occupies only a small fraction of the desktop market (four percent), the OS offers advantages for PC users.

Aside from more forgiving TPM requirements, Linux is free and open-source. This means it doesn't cost a penny. The development community also often supports drivers for older devices.

Linux comes with virtually no bloatware and few background processes. This can free up a lot of system resources for gaming. For instance, the recommended amount of system RAM for Windows 11 is 4GB. Lubuntu Linux can run with just 1GB. Still, if you enjoy PC gaming, you may worry about making the switch, given that many Windows games aren't available on Linux.

In this guide, you'll discover that Linux is perfect for gamers. Not only are developers increasingly releasing Linux versions of games, but there's a wide variety of distros designed with gamers in mind. You'll also discover how to play both classic and modern Windows games on Linux by using emulators and compatibility layers. **–NATE DRAKE**


A
Web Browser
Settings
Administration
Accessories
Development
Documentation
Education
Games
Graphics
Internet
Multimedia
Office
System
Log Out
Trash
Action Games
Adventures
Arcade
Blocks Games
Board Games
Card Games
Games for Kids
Logic & Puzzles
Role Playing Games
Simulations
Sports Games
Tactics & Strategy
Tux Typing
Advanced Strategic Command
Battle for Wesnoth
Bos Wars
Colossus
Freeciv
Freeciv modpack installer (gtk4)
Freeciv modpack installer (Qt)
Freeciv (Qt)
Freeciv Ruleset Editor
Freeciv server
FreeCol
LordsAWar!
MegaGlest
MegaGlest Map Editor
NetPanzer
OpenLieroX
Scorched 3D
Warmux
Warzone 2100

1 CHOOSE YOUR DISTRO

Most versions of Linux are suitable for playing Windows games. When researching this tutorial, for instance, we used stock Ubuntu 24.10, one of the most popular Linux distros.

» Alternatives included Pop!_OS, which has better built-in drivers for many Nvidia and AMD graphics cards. Linux Mint also has a built-in tool to double-check your hardware drivers are running the latest versions. This is important, as most Linux distros only use open-source software out of the box, to the exclusion of proprietary drivers.

» This can pose a problem when it comes to DirectX APIs. Fortunately the open-source graphics API Vulkan is able to utilize most DirectX calls present in Windows games.

» Some Linux distros are even specifically designed for gaming. Draguer OS, for instance, supports Vulkan, and comes with software like Steam, Lutris, GameHub, and PlayOnLinux.

» Other gaming-specific distros, like Nobara and Garuda Linux, also bundle Vulkan support, and include gaming software.

» Some mainstream distros also offer 'spins' of the OS that are tweaked for gaming. This includes Fedora 'Games Lab' [**Image A**], which is preinstalled with a selection of native Linux games.

» When choosing your distro, consider whether you want to use Linux as your daily driver OS or just for play. If you actually want to perform other daily tasks on the machine, like web browsing and word processing, you may prefer to install a general purpose distro like Ubuntu.

» The default 'flavor' of Ubuntu uses the GNOME desktop, which can be difficult to navigate for those coming from Windows. If this is a concern, choose an alternative flavor, like Lubuntu. This uses the LXQt desktop environment, which has a familiar application menu, taskbar, and so on. Ubuntu and its variants also have simple graphical setup assistants.

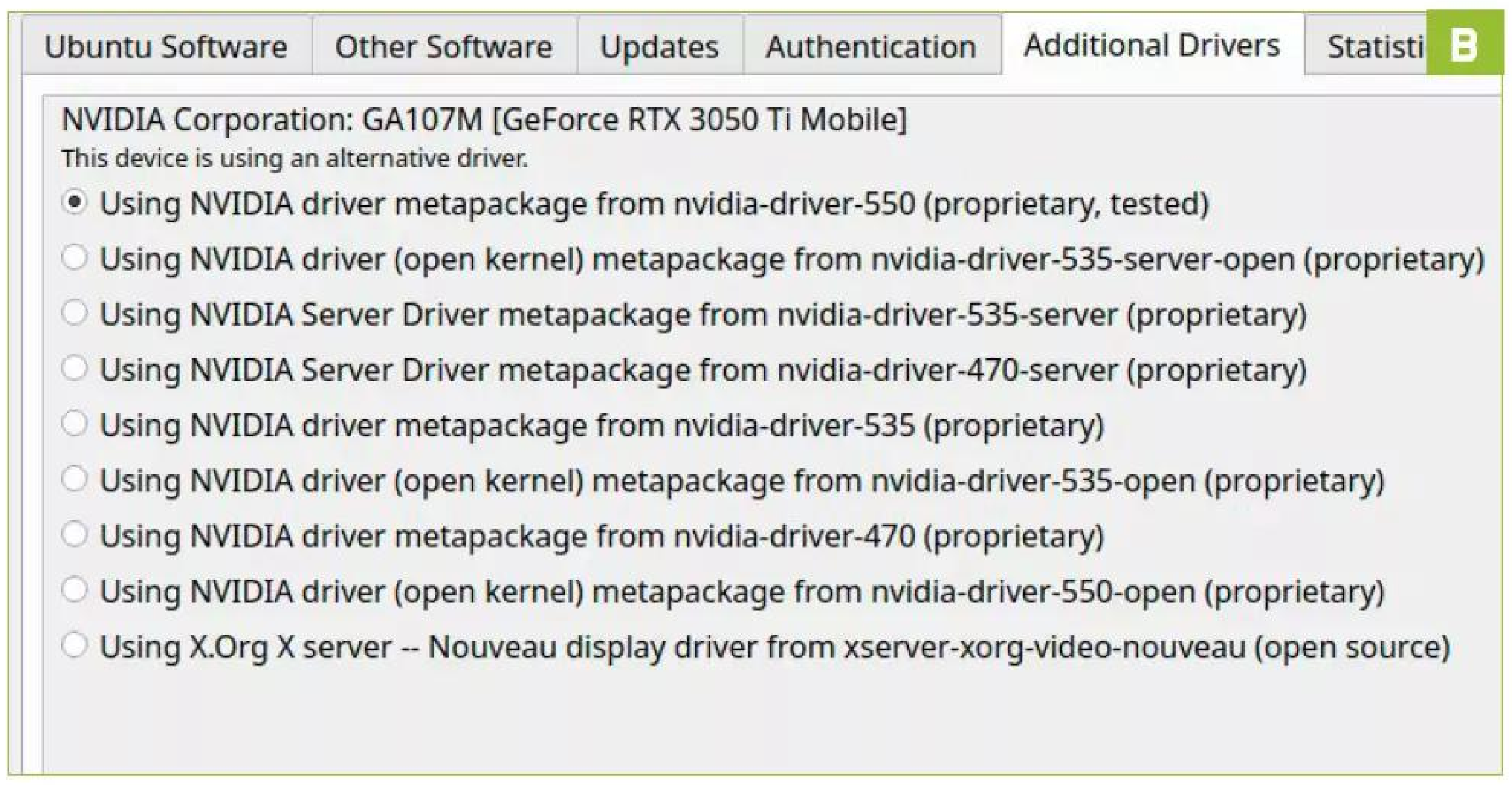
2 INSTALL LINUX VERSIONS OF GAMES

It stands to reason that the easiest way to play Windows games on Linux is to check if there is a Linux version.

» Developers are increasingly becoming aware of the demand for native Linux versions of their games. This is why popular titles like *Sid Meier's Civilization VI*, *Team Fortress 2*, and *Minecraft* all have Linux 'ports'.

» The exact steps you have to take to get these running depend on the specific game. Before you begin, it's best to check that you're using the best possible drivers for your GPU. These are usually proprietary.

» In Ubuntu, you can do this by searching for 'Drivers' in the activities bar to launch 'Additional Drivers' [**Image B**]. From here, you can choose to change to an appropriate binary driver for your system. If you don't


Ubuntu Software
Other Software
Updates
Authentication
Additional Drivers
Statisti
B

NVIDIA Corporation: GA107M [GeForce RTX 3050 Ti Mobile]
This device is using an alternative driver.
● Using NVIDIA driver metapackage from nvidia-driver-550 (proprietary, tested)
○ Using NVIDIA driver (open kernel) metapackage from nvidia-driver-535-server-open (proprietary)
○ Using NVIDIA Server Driver metapackage from nvidia-driver-535-server (proprietary)
○ Using NVIDIA Server Driver metapackage from nvidia-driver-470-server (proprietary)
○ Using NVIDIA driver metapackage from nvidia-driver-535 (proprietary)
○ Using NVIDIA driver (open kernel) metapackage from nvidia-driver-535-open (proprietary)
○ Using NVIDIA driver metapackage from nvidia-driver-470 (proprietary)
○ Using NVIDIA driver (open kernel) metapackage from nvidia-driver-550-open (proprietary)
○ Using X.Org X server -- Nouveau display driver from xserver-xorg-video-nouveau (open source)

© FEDORA PROJECT, CANONICAL

see any others listed, check with your GPU manufacturer to see if they offer Linux-compatible binaries.

» Most versions of Linux also don't come with Java preinstalled. This is necessary for some games, like the Linux edition of Minecraft.

» There's an open-source version of Java, known as OpenJDK, which is available in the repositories of most major distros. For instance, it can be installed via Ubuntu's Snap store. Alternatively, open Terminal, then run:

```
sudo apt install openjdk-17-jdk
```

» Once this is done, *Minecraft* fans can then download the necessary installer directly from the main website. In the case of Debian-based systems like Ubuntu, this involves a .DEB file, which you can right-click to open in the App Center.

» Once installed, the installer will, in turn, download the necessary files to run *Minecraft Java Edition*. Note that other versions, like *Bedrock* and *Minecraft Dungeons*, can't be played natively in Linux.

» Other titles, like *Civilization VI*, may need to be installed using third-party software like Steam, which we'll explore later in this tutorial. There is a Linux version of the Steam client.

» Titles like *Team Fortress 2* are available cost-free for Linux users who install via Steam. The same isn't true for all games. For instance, the Java edition of *Mincecraft* costs $29.99.

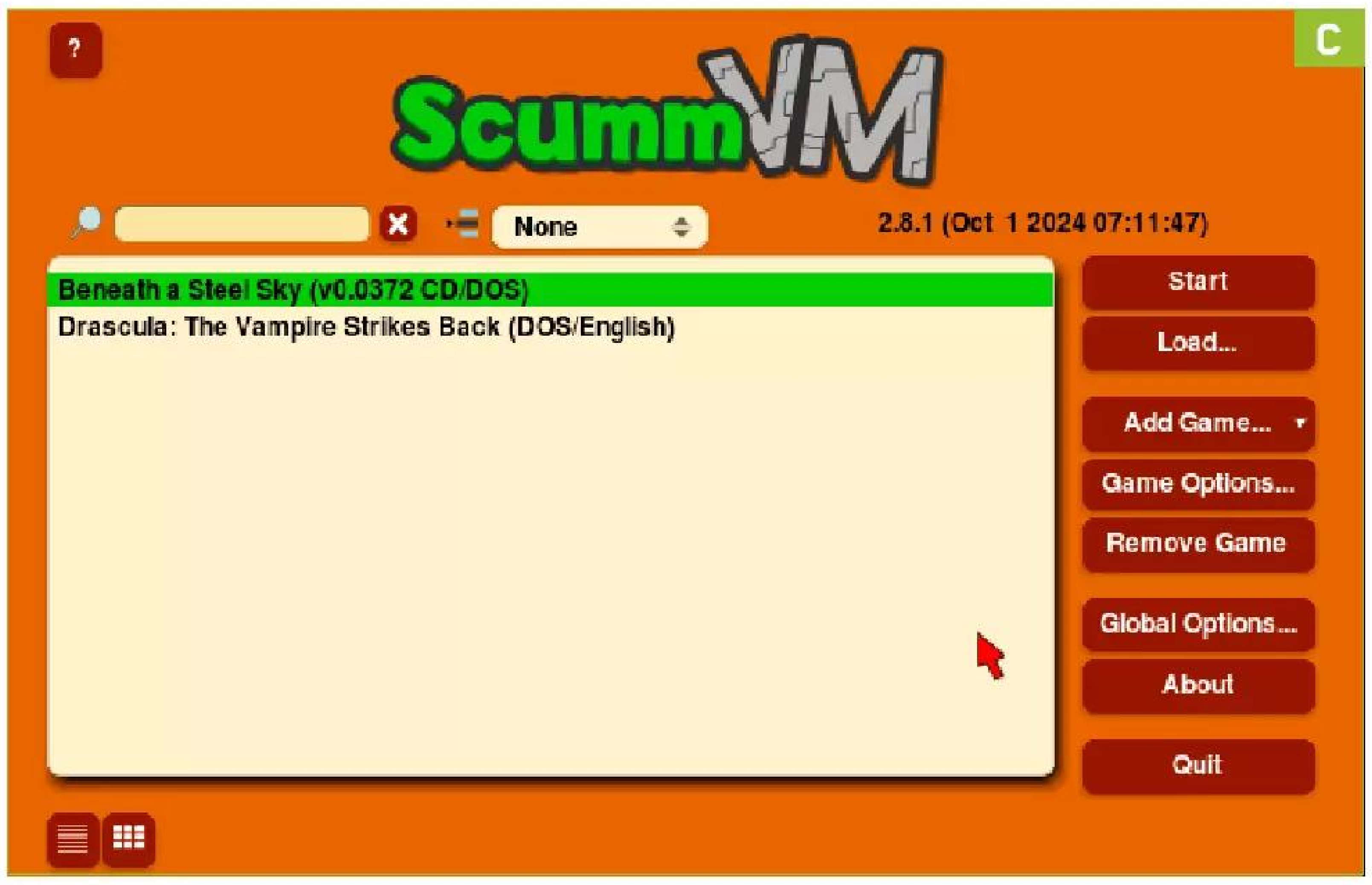
3

START YOUR ENGINES

If the developers haven't created a specific Linux version of the games themselves, it may still be possible to run it natively if they have released the source code. For instance, in 1997, iD published the code for the *Doom* game engine. This was quickly ported to run natively in Linux in engines like 'Chocolate Doom'.

» In the case of titles like *Doom* and *Quake*, while the engine is open-source, the level files and assets remain proprietary. This means you'll need a copy of the original Windows game files to play it legally on Linux.

» Many Windows classics have a thriving modding community, such as the Freedoom Project (https://freedoom.github.io). In this case, the developers have created levels from scratch, with entirely new assets, essentially creating a new game (pictured) while remaining loyal to the spirit of the original.



2.8.1 (Oct 1 2024 07:11:47)

Beneath a Steel Sky (v0.0372 CD/DOS)
Drascula: The Vampire Strikes Back (DOS/English)

» The same is true for the LibreQuake project, which also creates open-source levels and assets for Linux versions of the *Quake* engine, like *Quakespasm*.

» In most cases, you can just use the Terminal to install game engines, eg.

```
sudo apt install chocolate-doom
```

» Once you've downloaded or copied the level files to your device, switch to the folder where they're located, eg.

```
cd /home/nate/Downloads/freedoom-0.13.0
```

» You can then run the engine using the specified level files, eg.

```
chocolate-doom -iwad freedoom1.wad
```

» If your chosen Linux distro has a software center, feel free to explore the 'Games' category to find engines like these. We also recommend 'OpenRA', which is capable of playing the first games in the *Command & Conquer* series natively on Linux.

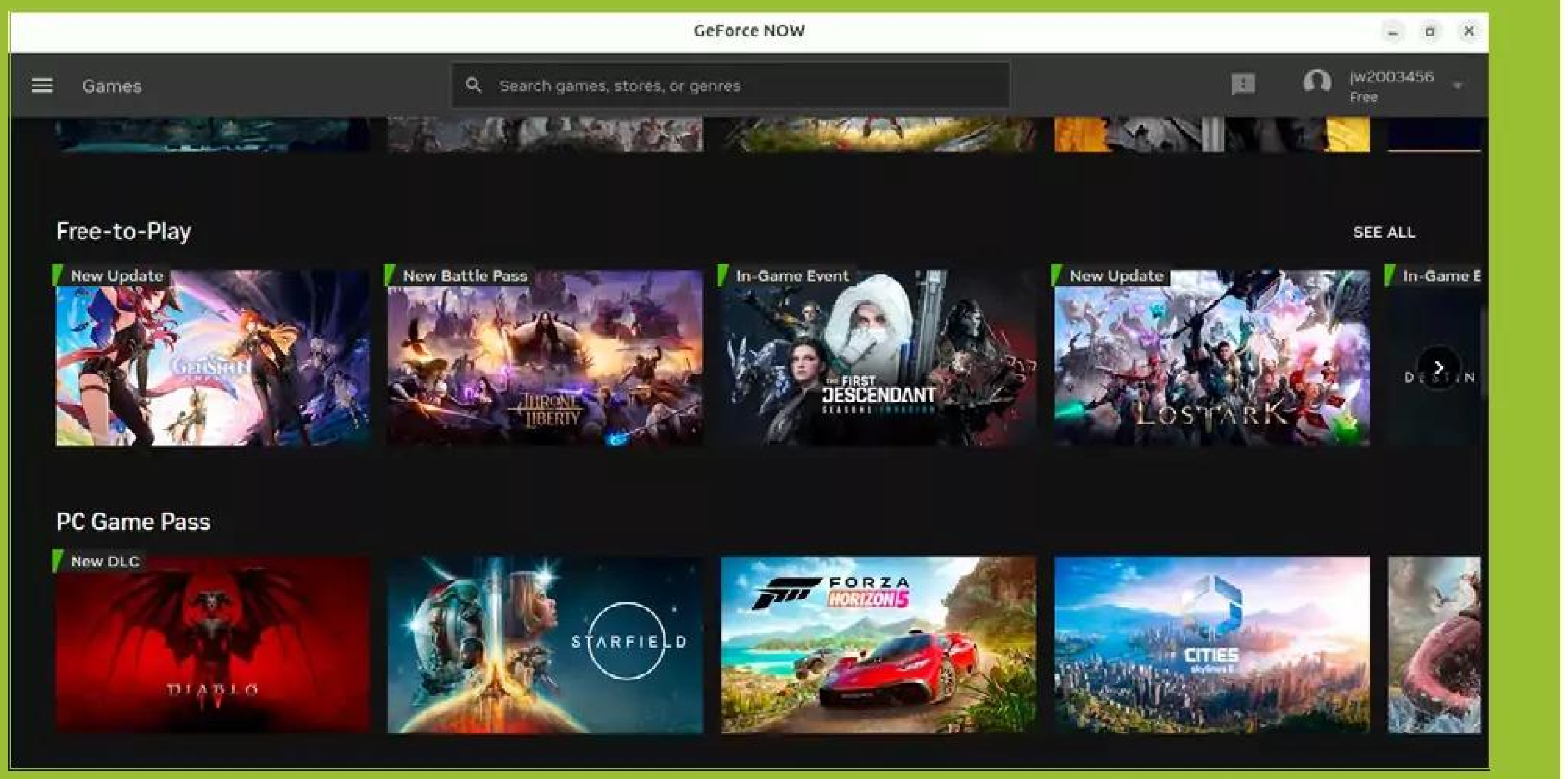
» As you browse titles, you may notice that some Linux games closely mirror Windows titles. For instance, *OpenTTD* is an open-source remake and expansion of *Transport Tycoon Deluxe*. The game mechanics and layout are very similar to the Windows original. The same is true for *Freeciv*, which is heavily inspired by *Civilization II*.

CLOUD GAMING ON LINUX

Generally speaking, domains and web apps load in Linux in the same way as they do on Windows. This means that Linux supports cloud platforms, though the degree to which it does so can vary.

For instance, the Ubuntu Snap store contains the Linux version of GeForce Now to allow users to stream games to devices. Xbox Game Pass holders running Linux can also make use of the cloud gaming service. However, we noted from the official support pages, as well as numerous frustrated comments on Reddit, that Firefox isn't supported.

Although this is one of the most common web browsers to come with Linux distros, this isn't a dealbreaker. Microsoft now offers both DEB and RPM Linux packages for its Edge browser. Linux users can also install Chrome in the same way. Alternatively, the open-source Chromium browser (on which both Chrome and Edge is based) is available in most Linux distro repositories.

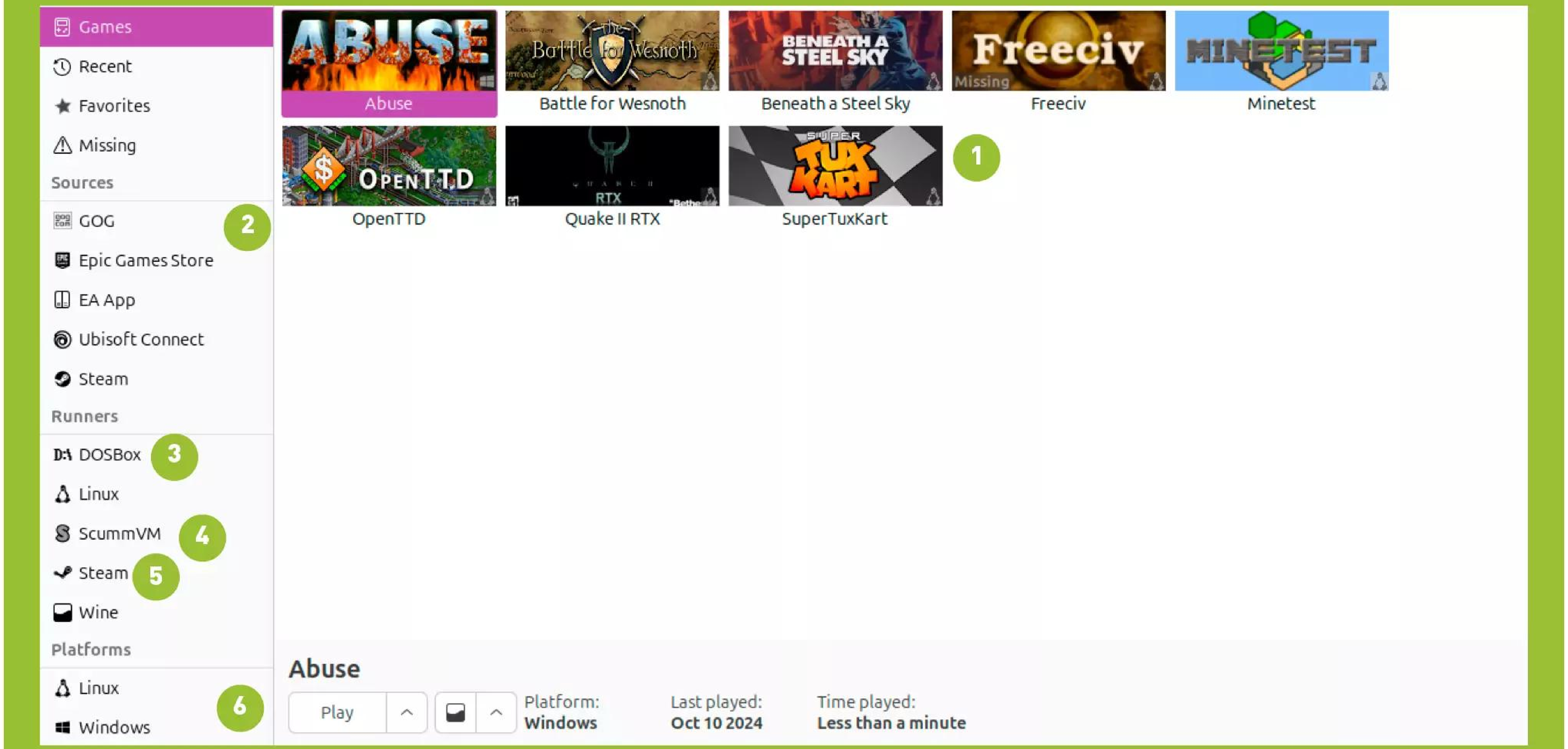


Certain platforms require further tweaking. For instance, we found a report of a Steam Deck user installing the Linux version of Edge to play Amazon Luna. However, this can result in an 'unsupported operating system' error message.

Linux users bypass this by tweaking the browser's User Agent string to make it appear as if it's running on Windows. Linux is fully compatible with Amazon's Luna controller.

© SCUMMVM TEAM, NVIDIA

WINDOWS GAMING ON LINUX



Abuse

Platform: Windows

Last played: Oct 10 2024

Time played: Less than a minute

1. LINUX GAMES

There are many excellent native Linux games. Some, like *Freeciv* and *OpenTTD*, are based on existing Windows titles, and have similar mechanics. Engines like Chocolate Doom can launch proprietary game levels.

2. GAME STORES

Multiple vendors now sell Linux titles alongside Windows. Lutris supports connecting to your game library to view and download these. GOG is particularly good for Linux gaming, as most titles are DRM-free.

3. DOSBOX

This utility allows you to launch DOS Classics like 'Abuse' on Linux machines. You can do this from the software's CLI. Alternatively, Lutris can automatically load and configure DosBOX.

4. SCUMMVM

This emulator supports loading and playing many Windows point-and-click adventure games, like *The Curse of Monkey Island*. Like DOSBox, you can install it directly or launch automatically via Lutris.

5. STEAM

The Linux client for Steam supports 'Steam Play'. This can run Windows games via the Proton compatibility layer. Many popular games, like *Red Dead Redemption II*, will work with minor tweaks.

6. MULTIPLE PLATFORMS

Game managers like Lutris and the Linux Steam Client support playing games both natively and via a compatibility layer, like Wine or Proton. Linux also supports most cloud gaming platforms.

4

GET SOME SCUMM

If you're a fan of point-and-click adventures, you should also install ScummVM. The SCUMM game engine was originally used for many LucasArts classics, like *The Secret of Monkey Island*. The open-source version of the engine can now play these and a number of other adventure classics.

» To get started on Debian-based systems like Ubuntu, open Terminal and run:

```
sudo apt install scummvm
```

» Next, you'll need to have access to the original game files so they can be loaded into ScummVM. If, like us, you don't have the original CD head to www.scummvm.org/games to see a selection of freeware and open-source titles, like the cyberpunk classic, *Beneath a Steel Sky*.

» Once you've downloaded or otherwise copied the necessary game files onto your device, start ScummVM. You can now select 'Add Game' to navigate to your chosen title. Before choosing 'Load' to begin your game, select 'Game Options'.

» From here, you can tweak settings like the 'Graphics' and 'Render' mode to make sure the game displays properly [**Image C**]. You can also toggle whether the game should be played in full screen.

» Take some time to explore the 'Keymaps' tab. This is where you can view and edit common commands such as to quit the game (default is 'Ctrl + Q).

» For a better playing experience, we recommend that you visit the 'GUI' tab and check the boxes next to both 'Return to the launcher when leaving a game' and 'Ask for confirmation on exit'.

» If you're unsure if your favorite game will function well in ScummVM, head to www.scummvm.org/compatibility. This contains a detailed database of English-language games, and rates their compatibility with ScummVM. The majority of games are awarded 'Good' or 'Excellent' compatibility, but some are listed as 'untested'. Buy at your own risk.

5

DUST OFF DOSBOX

As useful as ScummVM is for running classic adventure games, it only supports a limited number of titles. DOSBox is a command-line utility. It was originally developed in 2002 to provide continued support for DOS Programs, as Windows 3.0, 9.x and related programs were still based on MS-DOS.

© LUTRIS

» In theory, the DOSBox emulator can run any type of DOS Software, but it's best known for allowing people to play classic games like the *Civilization* and *Doom* series.

» If you have a particular DOS title in mind, our first advice is to fire up your Linux web browser and head to the Internet Archive (https://archive.org/details/softwarelibrary_msdos_games).

» As the link shows, the Archive has uploaded thousands of DOS classics, which you can play directly in your browser. Naturally, you'll need to check copyright laws where you live to see if this is legal. You may also find that certain functions, like saving and multiplayer, don't work when playing online in this way. [**Image D**]

» For a more authentic experience, install DOSBox via your Linux OS repositories, eg.

```
sudo apt install dosbox
```

» Next, create a working directory somewhere in your home folder for DOSBox to use e.g. 'DOS-GAMES'. Copy your game files into a folder inside this directory, eg. 'ABUSE'.

You can now launch DOSBox. First, enter the command to mount the game directory as your virtual C drive, eg.

```
mount c /home/nate/DOS-GAMES
```

» DOSBox will inform you that Drive C is now mounted using this directory. Type 'C:' to switch to the new drive.

» Next, you need to use 'CD' to enter the folder that contains the files for the game you want to play, eg.

```
CD ABUSE
```

» Type 'DIR' to view a list of all the files in the directory. You should now be able to view the executable, eg. ABUSE.EXE. Finally, enter the name of the executable to run the game.

6 LOAD UP LUTRIS

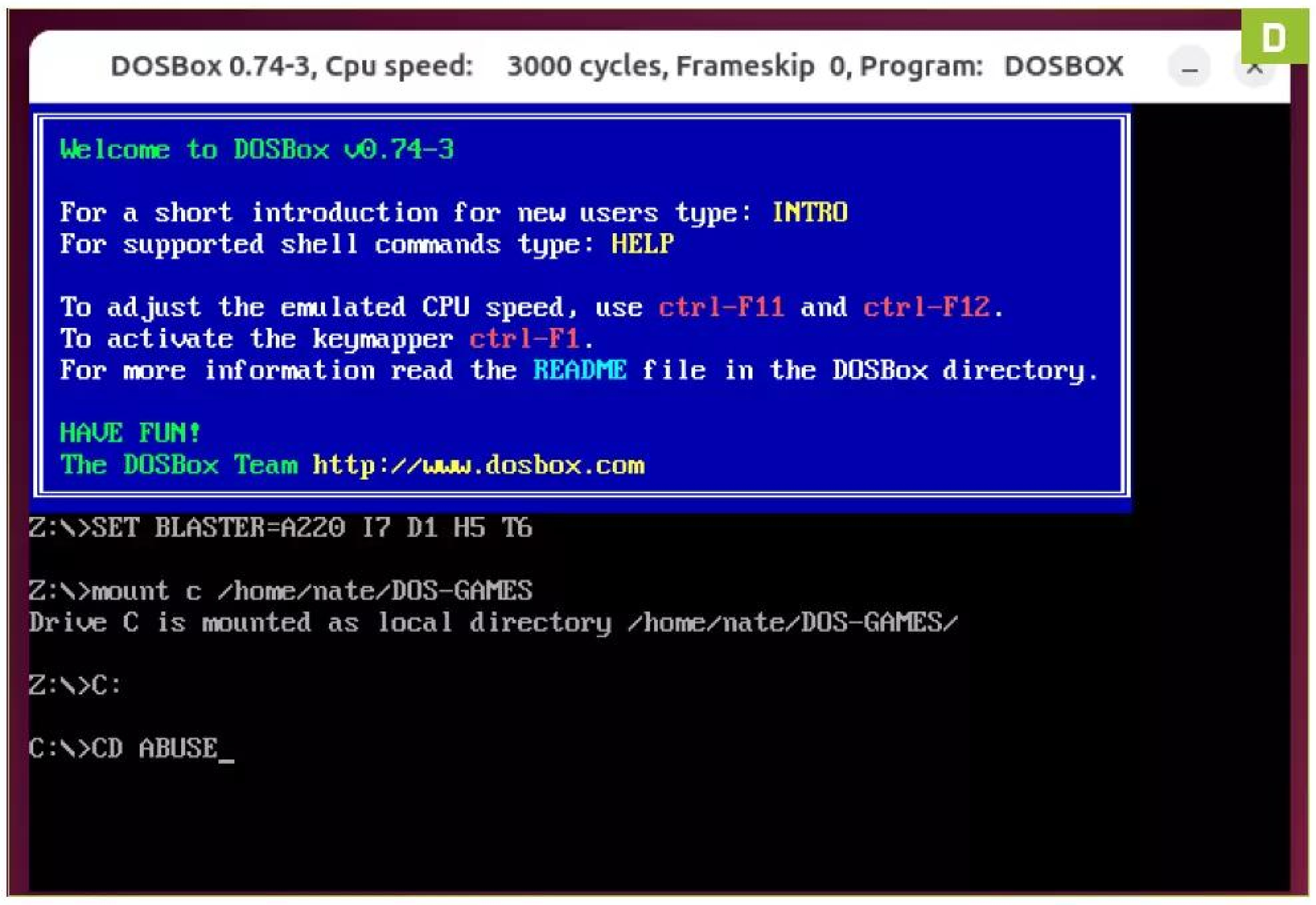
This open-source game manager serves as a frontend to a number of platforms. It supports running native Linux games, as well as those that can be run with emulators, like ScummVM and DOSBox.

» This means, for instance, that instead of entering commands to mount virtual drives in DOSBox, you only need to click '+' at the top left of the Lutris window ,and choose 'Install a Windows game from an executable'.

» Lutris incorporates the Wine compatibility layer, which is designed to run Windows programs on Linux. You can download and configure Wine yourself, but it's tricky to do so correctly.

» Lutris contains a number of community-created Wine configuration scripts, so if you select a common title (as we did for 'Abuse'), the correct Wine settings will automatically be applied. You then need only click on the game to launch.

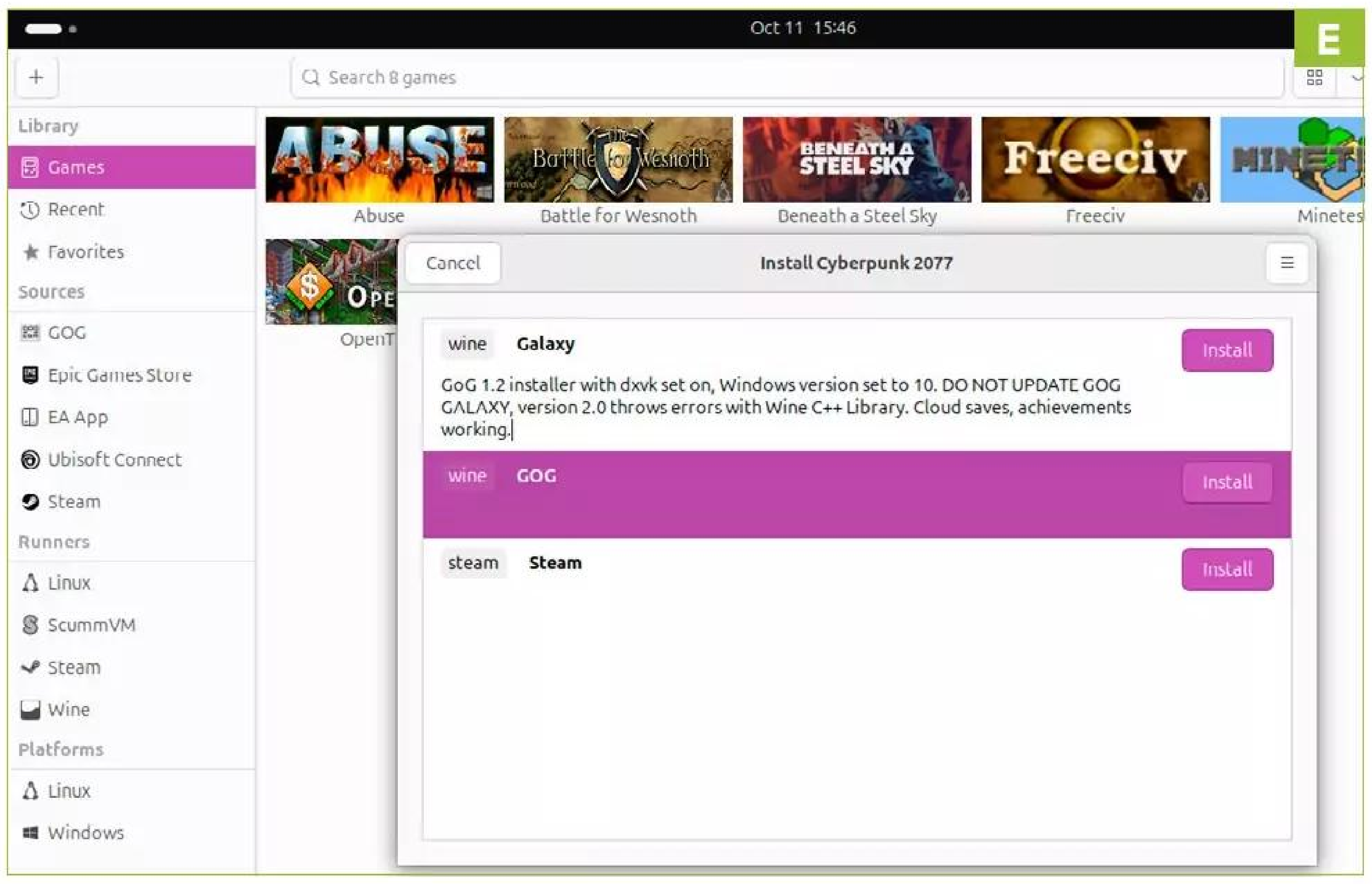
» The easiest way to check if your chosen game is supported is to click the '+' and choose 'Search the Lutris website for installers'. You'll then see corresponding installation options. For example, entering 'Cyberpunk 2077' shows installation scripts using the GOG Galaxy Client and the Steam client. [**Image E**]


D

DOSBox 0.74-3, Cpu speed: 3000 cycles, Frameskip 0, Program: DOSBOX

```
Welcome to DOSBox v0.74-3

For a short introduction for new users type: INTRO
For supported shell commands type: HELP

To adjust the emulated CPU speed, use ctrl-F11 and ctrl-F12.
To activate the keymapper ctrl-F1.
For more information read the README file in the DOSBox directory.

HAVE FUN!
The DOSBox Team http://www.dosbox.com
Z:\>SET BLASTER=A220 I7 D1 H5 T6

Z:\>mount c /home/nate/DOS-GAMES
Drive C is mounted as local directory /home/nate/DOS-GAMES/

Z:\>C:

C:\>CD ABUSE_
```

© DOSBOX


E

GoG 1.2 installer with dxvk set on, Windows version set to 10. DO NOT UPDATE GOG GALAXY, version 2.0 throws errors with Wine C++ Library. Cloud saves, achievements working.

» In theory, you can use the 'Sources' section to link various online gaming accounts like GOG and Steam to access your online libraries. During our tests with Lutris, however, we found that only one of the games in our GOG Library was listed.

» Assuming that this feature works for you, you can go to 'Preferences' > 'Sources' to add other online accounts besides those listed, including Humble Bundle and Itch.io.

» From here, you can also add, remove, and configure 'Runners'. These are emulators or engines that are capable of running games for other platforms. By default, only Linux, Steam, and Wine are enabled, but this is sufficient to run most Windows titles.

7 SWITCH TO STEAM

There's a Steam version of the Linux client. If you have a Linux-compatible game, like *Quake II RTX*, in your library, you can start playing by simply clicking 'Install'.

» However, if you try to select any Windows games in your library, by default, Steam grays out the install button.

» You can fix this by enabling Proton. This is a compatibility layer based on Wine, which supports playing most Windows games on Linux. Proton is built into the Steam client under the name 'Steam Play'.

» Check if your chosen title is Proton-compatible by visiting www.protondb.com. Games that run well via Proton include popular Windows titles like *Red Dead Redemption II* and *GTA V*.

» Next, open the client and choose 'Steam' > 'Settings'. Select 'Compatibility' from the left-hand pane, then activate 'Enable Steam Play for all other titles'. This instructs Steam to try to run all Windows games through Proton. By default the experimental version of Proton is used for this. You can change this to a previous, stable version via the drop-down menu.

» Not all games are compatible with Proton. However, there's some anecdotal evidence online that certain Windows titles run better with Steam Play on Linux than they do natively. This is probably because Linux is designed more efficiently. See our guide on page 60 for more information on removing Windows bloatware.

Use Windows Mobile Hotspot

YOU'LL NEED THIS

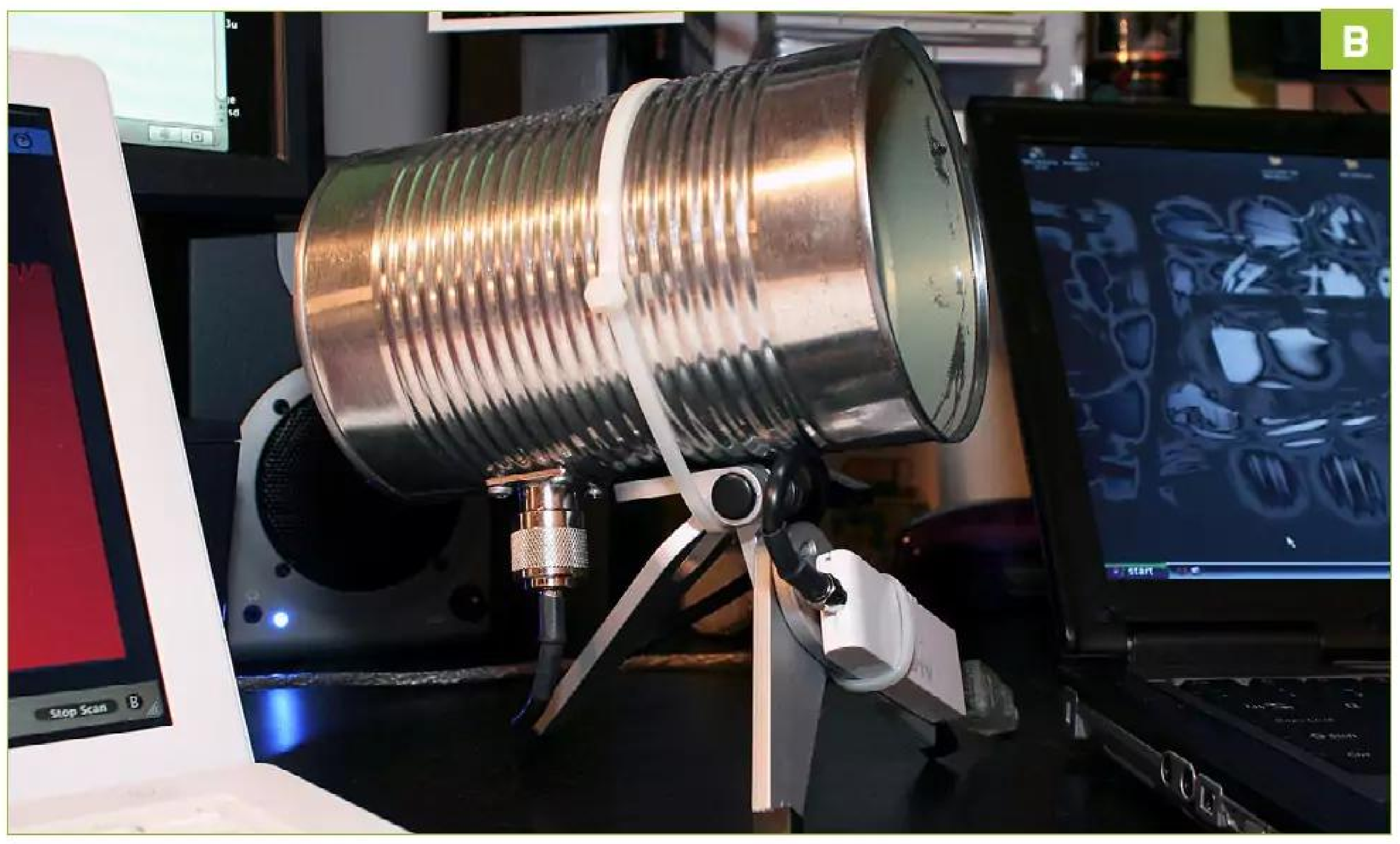
INTERNAL WIRELESS CARD
ETHERNET CONNECTION
WI-FI 6 USB WIRELESS ADAPTER (Optional)
BLUETOOTH 5.0 ADAPTER (Optional)

IF YOUR WINDOWS 11 device has an existing Wi-Fi, cellular, or Ethernet internet connection, you can share this wirelessly via Windows' Mobile Hotspot.

This is particularly useful if you're in a situation where the Wi-Fi card antenna in your laptop or PC can connect to the network without issue, but other devices, like cellphones, struggle to maintain a strong signal. In this case, you can generate a mobile hotspot to which other nearby devices can connect and take advantage of your Windows device's stronger internet connection.

If your Windows machine connects directly via Ethernet, but has an internal wireless card, you can use the Mobile Motspot feature to generate a wireless network to share the connection with other devices.

Windows 11 supports sharing your connection both by Wi-Fi and Bluetooth. You'll discover how to set up Mobile Hotspot, then optimize it for Windows 11. **–NATE DRAKE**



1 CHOOSE YOUR HARDWARE

If you're looking for a long-term solution for sharing your internet connection wirelessly, there are more practical methods than Mobile Hotspot. These include using 'mesh' systems.

» Mobile Hotspot represents a quick and simple way to allow devices to connect to a wireless network you generate on an ad-hoc basis. There are few configuration options, and by default the hotspot will be disabled if no devices are connected.

» This means you should think carefully before buying any specialist equipment. If your device supports Bluetooth, you can share a Wi-Fi or Ethernet connection just by pairing other devices with your Windows machine.

» However, if you're planning to buy a new laptop soon, you'll get the best hotspot performance from Wi-Fi cards that support 802.11ax (Wi-Fi 6). Intel's Wireless-AC 9560 and Killer Wi-Fi 6 AX1650 are perfect for this purpose.

» Desktop PC users should opt for PCIe Wi-Fi cards. For example, the TP-Link Archer TX3000E [**Image A**] offers Wi-Fi 6 speeds of up to 2402 Mbps on the 5GHz band. It also supports Bluetooth 5.0, so you can use the same device to connect to Wi-Fi, then share your connection via mobile hotspot.

» If your device connects to the internet via Wi-Fi, and you want to share the connection in the same way, you'll need to generate a separate Wi-Fi network. The easiest way to do this is by using a USB Wi-Fi adapter. The Netgear Nighthawk A8000, for instance, supports the latest Wi-Fi 6E standard, meaning that it can connect to 6GHz, as well as 5GHz and 2.4Ghz networks.

» Naturally, you will get the best connection quality if you choose network cards or adapters that have external antennas.

» You can attach a 'cantenna' [**Image B**] to an existing USB Wi-Fi adapter to amplify Wi-Fi signals (from 5 to 22db in most cases). If you do this, you'll need an N-female connector and pigtail cable to connect the can to the Wi-Fi adapter. For the best results, choose a can that's 3.25 to 3.75 inches wide.

2 SET UP YOUR WI-FI HOTSPOT

To get started, simply enter 'hotspot' into the Windows search bar to open Mobile Hotspot.

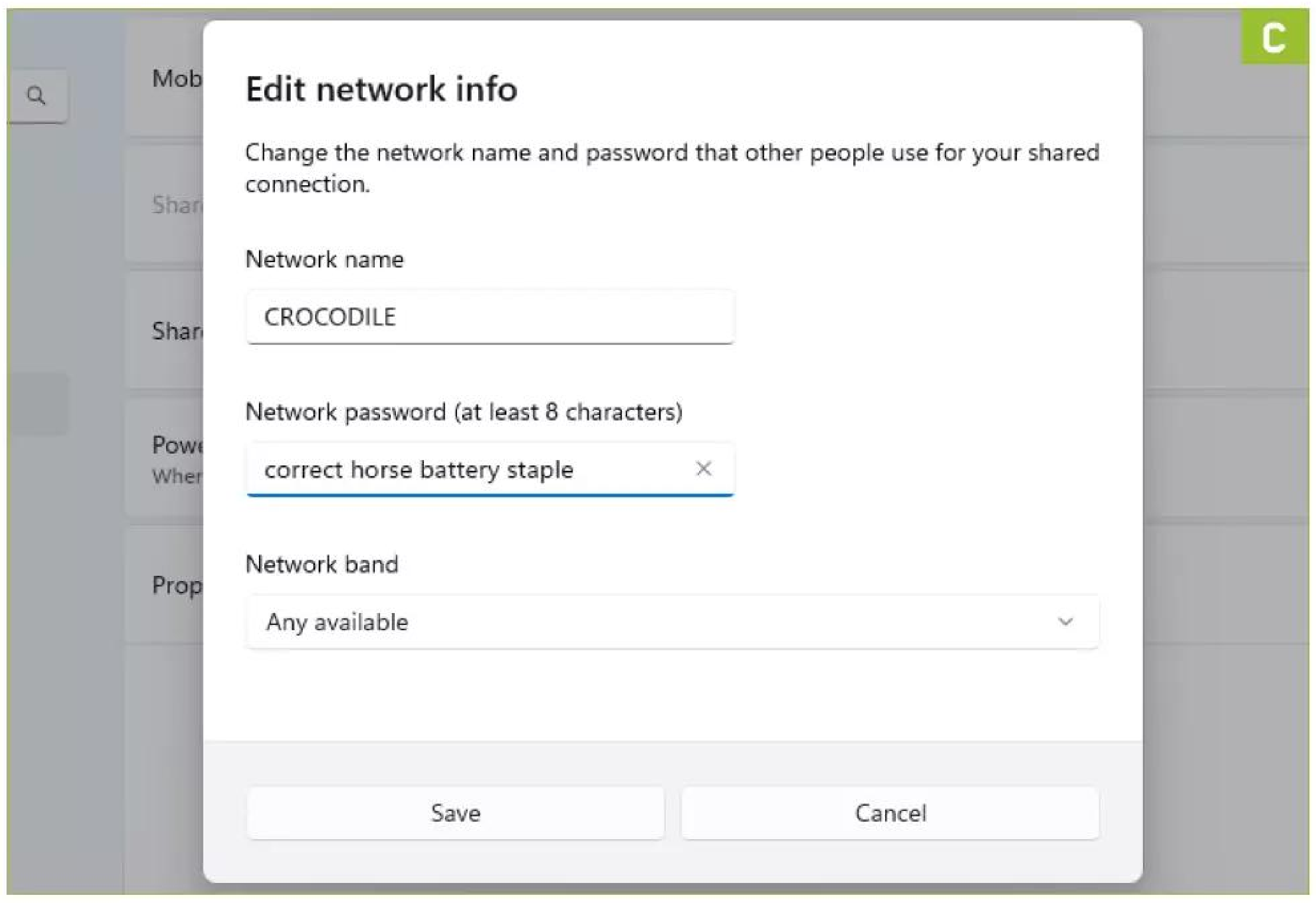
» By default, this feature is switched off. If your device has an Ethernet connection to the internet as well as a Wi-Fi card, you can broadcast your network immediately. Simply hit the rocker switch at the top of the window to activate Mobile Hotspot.

» In the drop-down menu marked 'Share my internet connection from', select 'Ethernet'. Leave the 'Share Over' menu set to its default value (WiFi).

» The 'Power saving' section governs whether or not the hotspot will be deactivated if no devices are connected to it. Enable or disable this as you see fit, then move down to expand the 'Properties' section.

» From here, you can view and modify the wireless network settings. By default, the network name is based on your device. Click 'Edit' to set a new, recognizable

© TP-LINK, WIKIPEDIA/CC



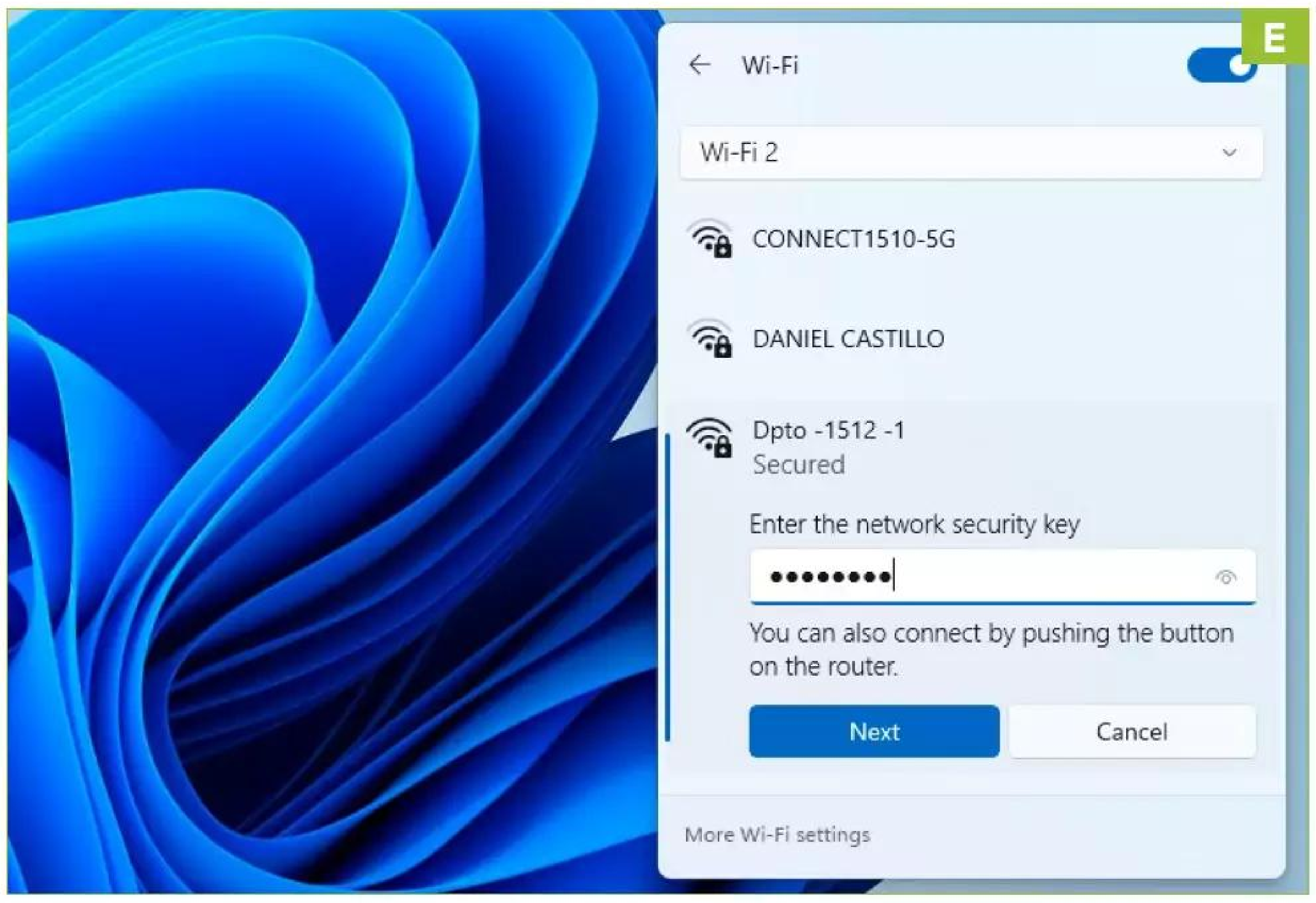
Edit network info

Change the network name and password that other people use for your shared connection.

Network name: CROCODILE

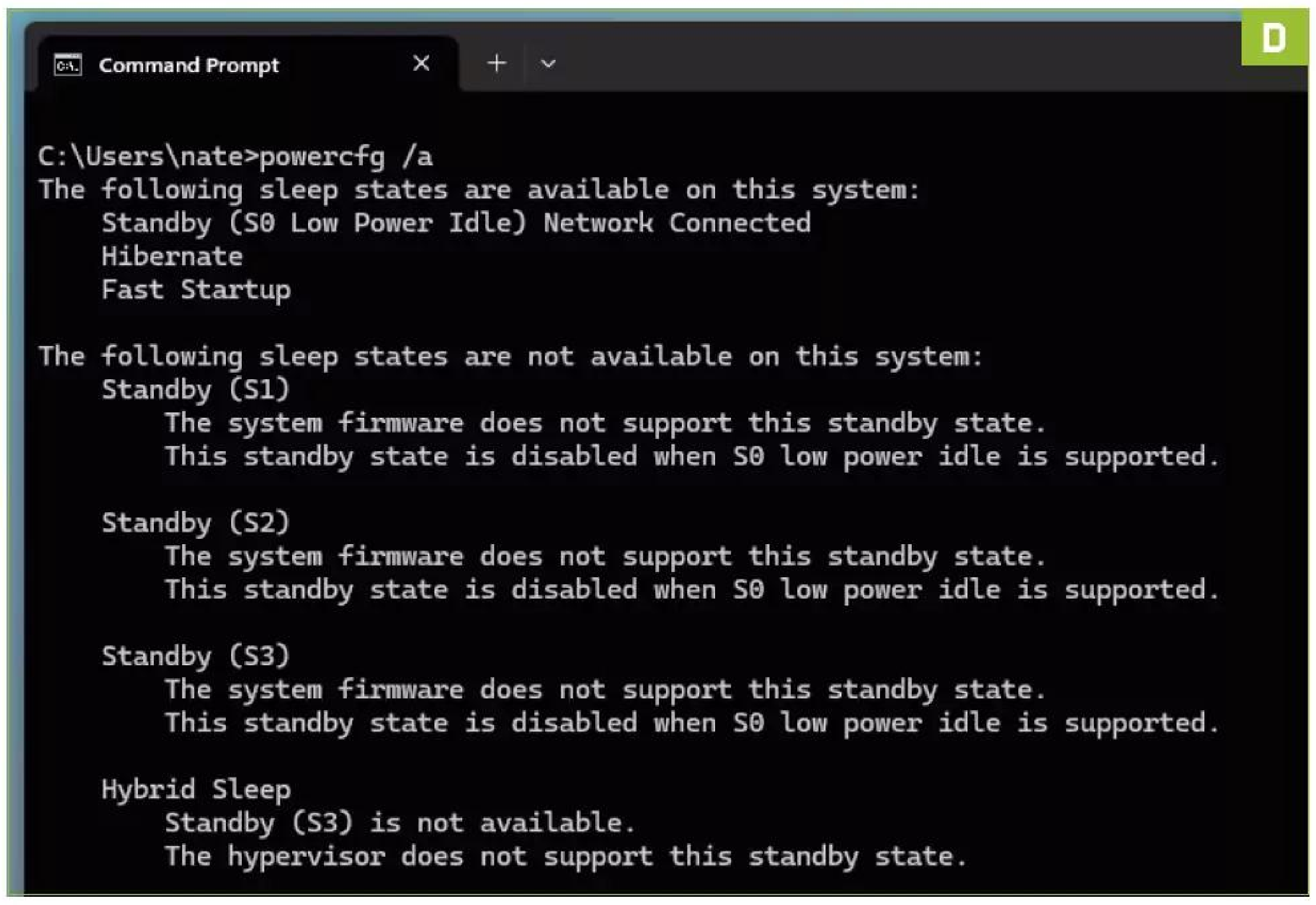
Network password (at least 8 characters): correct horse battery staple

Network band: Any available

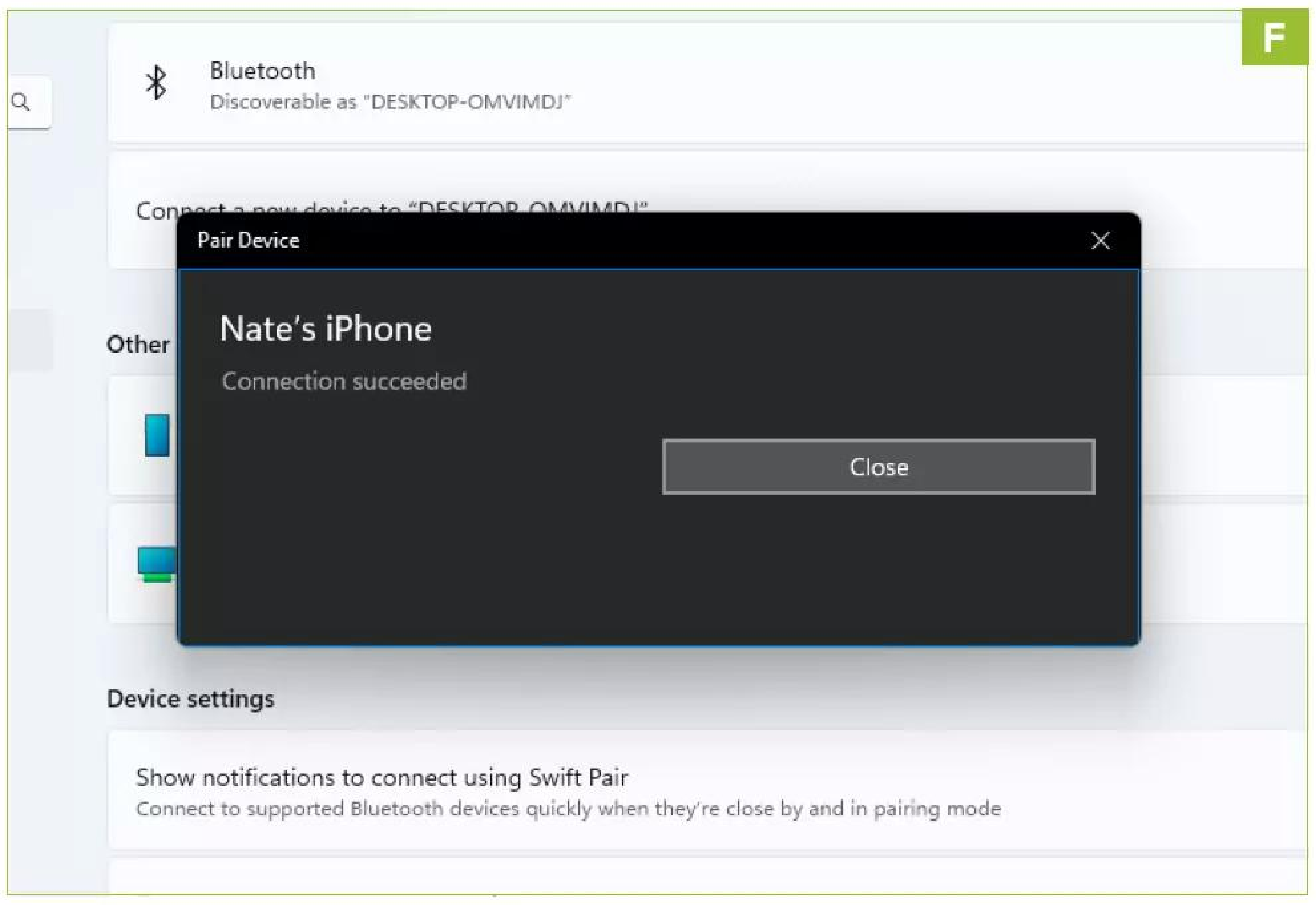


Enter the network security key: ••••••••

You can also connect by pushing the button on the router.



```
C:\Users\nate>powercfg /a
The following sleep states are available on this system:
    Standby (S0 Low Power Idle) Network Connected
    Hibernate
    Fast Startup

The following sleep states are not available on this system:
    Standby (S1)
        The system firmware does not support this standby state.
        This standby state is disabled when S0 low power idle is supported.

    Standby (S2)
        The system firmware does not support this standby state.
        This standby state is disabled when S0 low power idle is supported.

    Standby (S3)
        The system firmware does not support this standby state.
        This standby state is disabled when S0 low power idle is supported.

    Hybrid Sleep
        Standby (S3) is not available.
        The hypervisor does not support this standby state.
```



Nate's iPhone

Connection succeeded

Show notifications to connect using Swift Pair

Connect to supported Bluetooth devices quickly when they're close by and in pairing mode

name, e.g. 'CROCODILE'. Windows 11 uses a string of eight random characters for the Wi-Fi key.

» Change this to a stronger passphrase. We recommend Diceware (https://diceware.dmuth.org) for generating high-entropy but easy-to-remember passwords. [**Image C**]

» Unfortunately, Windows 11 doesn't support changing Wi-Fi security settings. We discovered that the wireless networks generated on our test machine used WPA2-PSK (AES), but compatible wireless cards may also support WPA3. There's also no support for using hidden SSIDs.

» Once you've entered your new network name and strong password, choose 'Save'. Your new Wi-Fi network should now appear on the network menu of nearby devices.

» Hotspots only function while your Windows device is active. More recent machines support 'Modern Standby' to maintain network connections, even when in 'sleep' or 'low power' mode.

» You can check if your Windows machine supports this by opening the command prompt and running:

```
powercfg /a
```

» If 'S0 Low Power Idle' isn't available, you may need to adjust your device's sleep settings to keep the hotspot active. [**Image D**]

3 USE MOBILE HOTSPOT WIRELESSLY

In the previous step, we covered sharing an Ethernet connection using your device's internal Wi-Fi card. If your device already uses wireless to connect to the Internet, you'll likely need a separate Wi-Fi adapter to share your connection.

» Once the device is connected, enter 'WiFi' into the Windows search bar to open 'Wi-Fi settings'. The USB wireless adapter will be listed underneath your principal wireless interface— e.g. as 'Wi-Fi 2'. Select the network menu underneath, and connect to your usual wireless network. This will leave your device's internal Wi-Fi card free to generate the hotspot.

» Open the Mobile Hotspot settings. In the 'Share my internet connection from' drop-down menu, choose 'Wi-Fi'. Leave the 'Share over' menu set to 'Wi-Fi'.

» You can now choose to enable power saving as you see fit, then 'Edit' the properties of your new wireless network as outlined in the previous step. At this stage, you can connect other devices to the new Wi-Fi network. If you do this, remember that all data from connected device has to travel across two wireless connections.

» Your Windows machine also has to manage routing between two wireless interfaces, which can cause processing delays. This means you're unlikely to see blistering-fast internet speeds, even if your router has a nominally high-speed connection.

» If both wireless adapters are using the same router channel, they can also interfere with each other. If this happens, check if your router supports setting up a separate 5GHz/6GHz network, to which you can connect the adapter. Other devices can then connect to the mobile hotspot's 2.4GHz network with less risk of interference.

» Bluetooth connections are generally slower, but are a great way to share your internet connection if you don't have an external adapter.

» To get started, return to settings and select 'Bluetooth' from the 'Share Over' menu.

» Next, open Bluetooth settings from Windows. Ensure that your device is enabled. You can now pair external devices like an iPhone to use the hotspot's internet connection. [**Image F**] ⏻

© MICROSOFT

Turn your phone into a wireless webcam

YOU'LL NEED THIS

ANDROID PHONE OR TABLET
(sorry, iPhone users)

WINDOWS 11

WE'VE ALL GOT A WEBCAM, but most of them are built into the bezel that surrounds a laptop screen, or connected to the back of a desktop PC by a wire. They can be pretty good, but there's another camera we carry with us everywhere: the one in our cellphones.

You can use it as a wireless webcam for your Windows 11 machine—as long as it's an Android phone (Apple users can do something similar with an iPhone and Mac in the Continuity Camera feature, and Windows has similar third-party apps), and you've enrolled it in the Link to Windows program by installing Microsoft's app. It'll need Android 9 (Pie) or later, but as that version was released in 2016, you should be fine. We used a Google Pixel 6 running Android 14—not the newest phone, but the latest OS at the time of writing—and it worked almost seamlessly.

The cameras on your phone can be of higher quality than pinhole webcams on even the best PCs, and the ability to wander around with the camera can be useful, too. Here's how it's done.

–IAN EVENDEN

1 GET SET UP

Firstly, you'll need Windows 11— version 1.24012 or later of the Link to Windows app that runs on your phone (we used 1.24091 from October 13, 2024). The Phone Link app that runs on Windows shares the same update number, so check that in the General section of its Settings menu, and update it if necessary. Then, make sure Wi-Fi and Bluetooth are activated on both your PC and smartphone—open both the apps, and sign into them with the same Microsoft account.

2 GIVE PERMISSION

Modern versions of Android are well locked down when it comes to apps' access permissions. You'll need to accept several different types, including connecting to nearby devices, accessing the camera, and allowing the app to run in the background. If you're worried about potential privacy breaches, you can open the App Permissions section of the Android Settings app, and force Link to Windows to ask every time it wants to access the camera.

3 BACK ON THE PC

Open Windows' Settings app, and search for 'mobile devices'. It's nestled under 'Bluetooth and devices' in the hierarchy, in between printers and cameras. In the pane that opens, switch on the 'Allow this PC to access your mobile devices' and 'Phone Link' options—you might need to sign into your Microsoft account once again, or provide your PC's PIN. Click the 'Manage devices' button and, if your cellphone doesn't appear on the list, click 'Add device'. This will take you through the process of helping the two bits of tech get to know one another—it's very similar to pairing a Bluetooth device, and will involve checking if a code displayed on both screens is the same.

4 ACTIVATE THE CAMERA

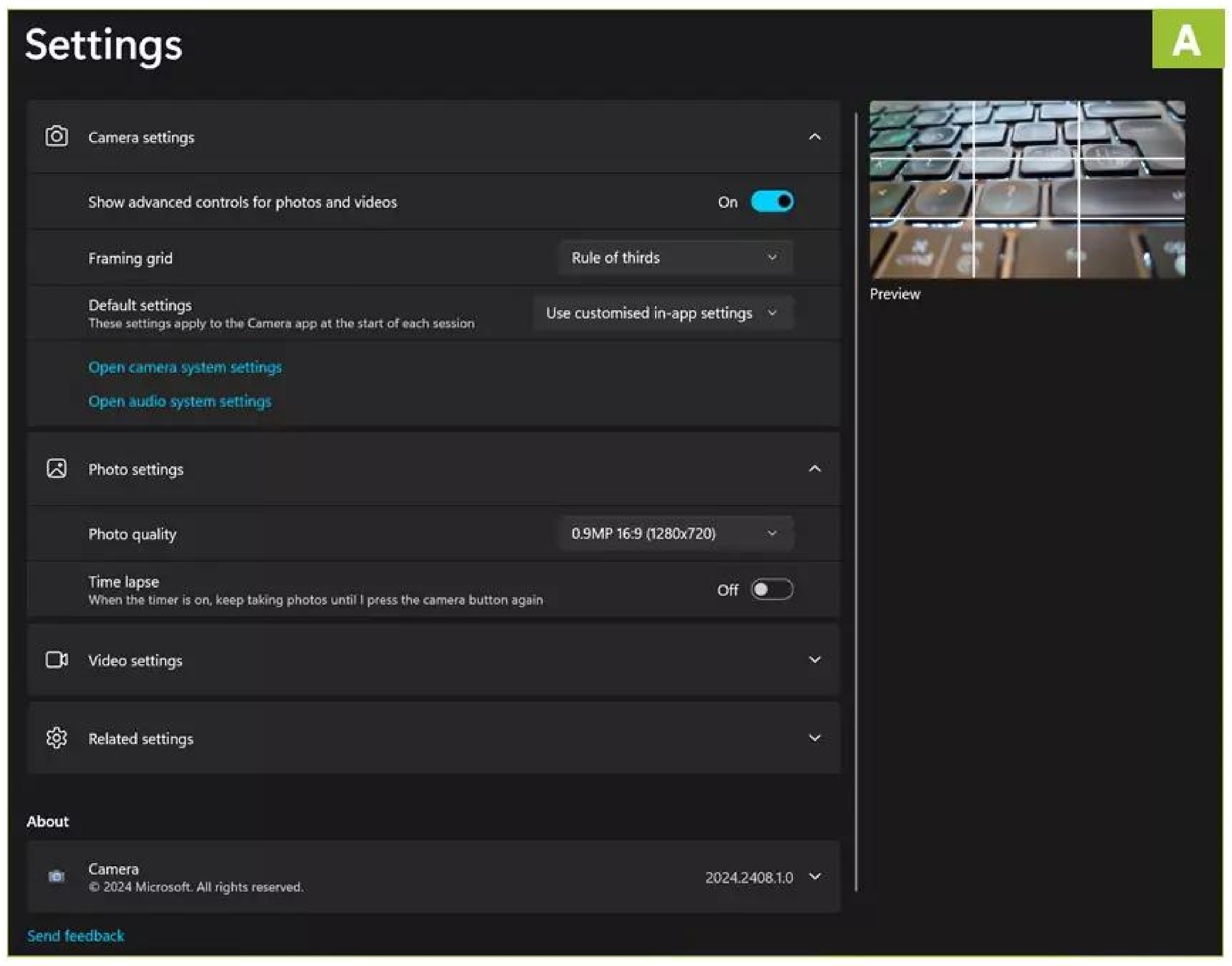
In the 'Manage mobile devices' window is an important setting: 'Use as a connected camera'. This is the bit that makes the whole thing work. You'll need the device to be enabled, then you'll be able to slide the switch to 'on'. There's another option beneath it, 'Get new photo notifications', which sends photos you've taken directly to the PC for editing in the same way a tethered DSLR or mirrorless camera can be connected to a PC running something like Lightroom or Capture One, so that the image can be viewed on a larger, more color-accurate screen, or immediately sent to the cloud, but this is less of a necessity for what we're doing here. If you want to use it, however, it even works with screenshots, and opens the file in the Snipping Tool window so that you can crop, markup, and save it.

5 START USING YOUR NEW WEBCAM

A good way to test if it's all working properly is to open Windows' built-in Camera app—search for it in the Start menu. If all has gone to plan, you should now be able to access a camera with the same name as your smartphone—Pixel 6, in our case. You may get a notification on your phone asking for permission to proceed. Don't swipe it out of the way, as once you've done this, it can be tricky to get back, and you may have to start the process over again, or restart your phone.

6 CAMERA APP

Once you've got the stream running in the Windows Camera app, you can operate it a lot like the Camera app on your phone [**Image A**]. If you've got more than one camera connected, you might need to unplug or disable the other one: a Logitech camera we had attached via USB was a far better prospect as far as



Settings

Camera settings
Show advanced controls for photos and videos: On
Framing grid: Rule of thirds
Default settings: Use customised in-app settings
These settings apply to the Camera app at the start of each session
Open camera system settings
Open audio system settings

Photo settings
Photo quality: 0.9MP 16:9 (1280x720)
Time lapse: Off
When the timer is on, keep taking photos until I press the camera button again

Video settings

Related settings

About
Camera 2024.2408.1.0
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Send feedback

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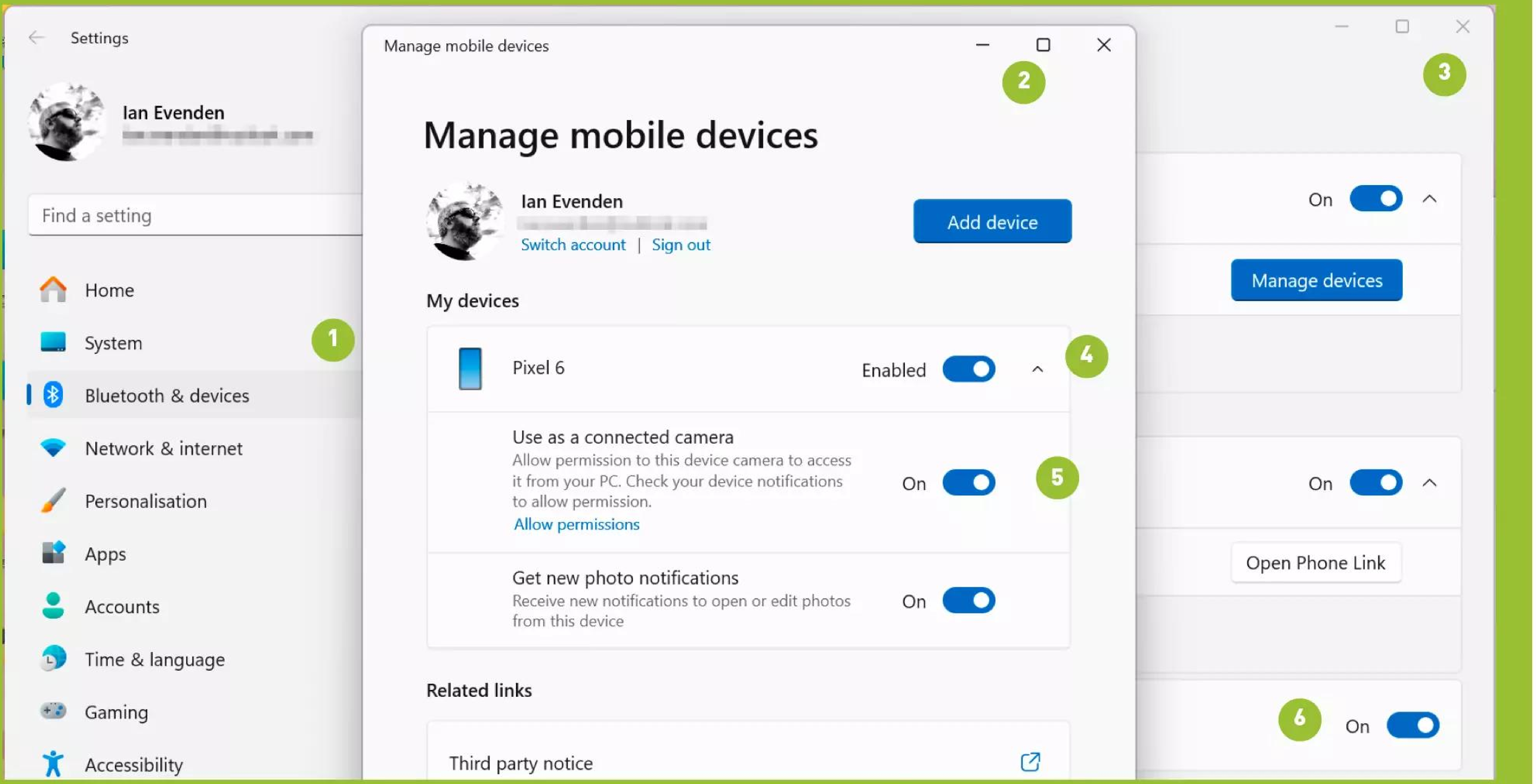
THE MOBILE DEVICES WINDOW


Settings
Ian Evenden
Find a setting
Home
System
Bluetooth & devices
Network & internet
Personalisation
Apps
Accounts
Time & language
Gaming
Accessibility
1
2
3
4
5
6
Switch account | Sign out
Add device
Manage devices
Open Phone Link
Related links
Third party notice

Manage mobile devices

Ian Evenden

My devices

Pixel 6 — Enabled: On

Use as a connected camera — On
Allow permission to this device camera to access it from your PC. Check your device notifications to allow permission.
Allow permissions

Get new photo notifications — On
Receive new notifications to open or edit photos from this device

1. FIND IT
Look under 'Bluetooth and devices', or search for 'mobile devices'.

2. ADD DEVICE
This is where you'll need to go to in order to add your phone as a webcam.

3. THE BIG SWITCH
You can't see it here, but this toggle belongs to the big 'Allow your PC to access mobile devices' option.

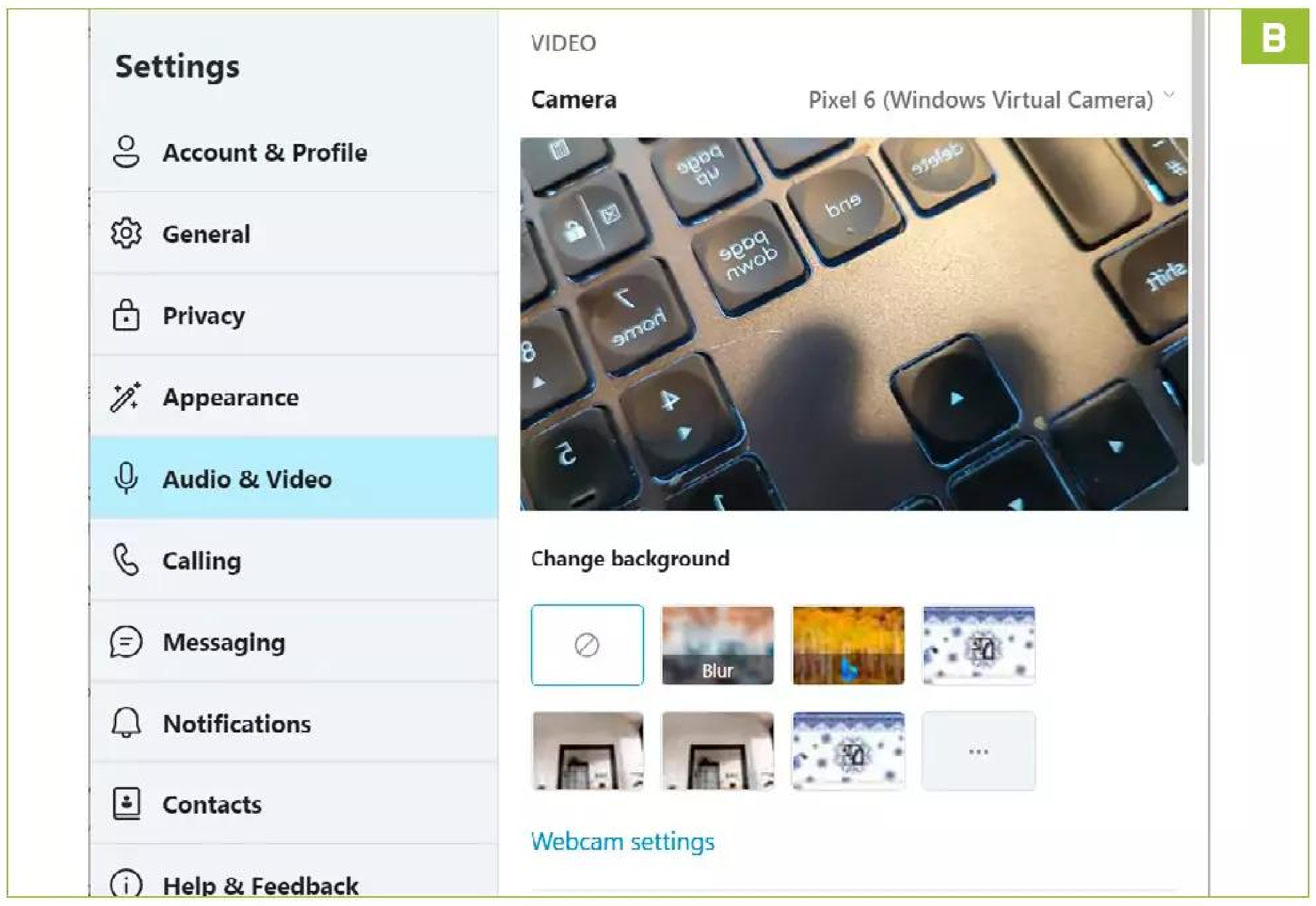
4. ENABLER
If you have multiple mobile devices connected, you can simplify things by switching some off here.

5. USE AS A CAMERA
The important one for our needs. Without this switched on, the camera won't stream.

6. DO YOU NEED HELP?
You might want to switch this one off. It asks Windows to make suggestions about how to use your mobile device.

the Camera app was concerned, and seemed to have become the default, with no way to switch.

Once you're using the right one, the camera feed fills the window, and there's a control at the side to switch between video and stills capture, with a barcode scanner as a third option. A settings menu at the top left opens to supply more settings, including the ability to change the resolution of the stills and video (which were both locked to 720p for us), a time-lapse setting that takes photos until you press the button a second time, and whether the camera can embed location info into the files it produces. At the top, you can also activate a framing grid (with various options, including rule of thirds) and test out 'new, experimental features'—when we tried it, it did nothing. A preview of your camera feed is displayed at the top right. In the Android app, there are two options: the ability to switch between front and rear cameras (but not ultrawide or telephoto lenses), and an 'Effects' menu that lets you swap between 'normal' and 'night' modes. Then, in the Cameras section of the Windows Settings app, you'll find a setting to rotate the video feed.


B
Settings
Account & Profile
General
Privacy
Appearance
Audio & Video
Calling
Messaging
Notifications
Contacts
Help & Feedback
VIDEO
Change background
Blur
Webcam settings

Camera: Pixel 6 (Windows Virtual Camera)

7 USE WITH APPS

Your new camera appears in most apps as a normal webcam, so you'll be able to switch to it as you would any other camera using the app's settings. [Image B] shows the settings window from Skype, where all the usual options are present.

8 TURN IT OFF

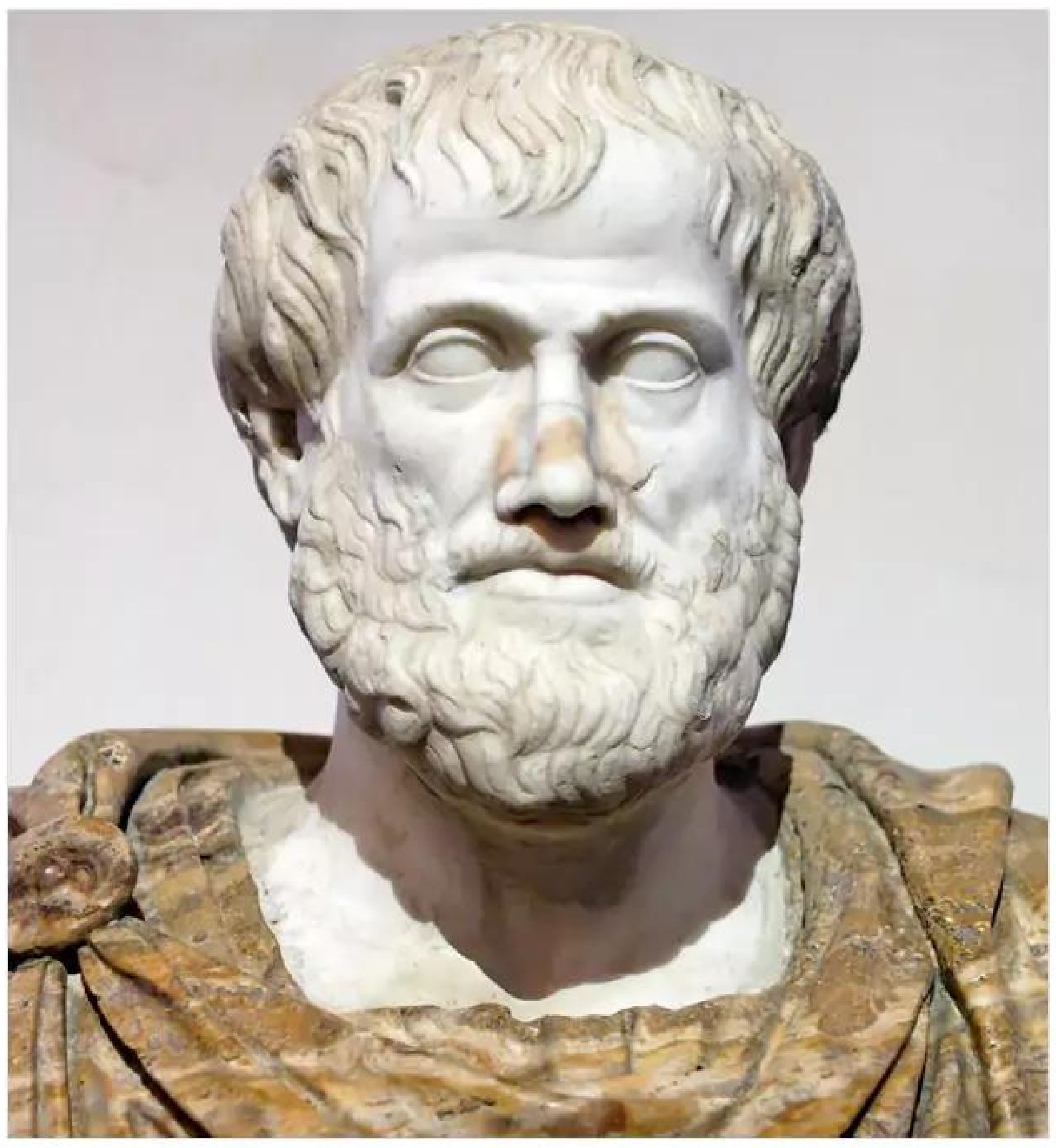
Lock your camera screen, and the connection isn't terminated, but the stream pauses. To start again, you'll need to unlock your phone and tap the 'resume video' icon. Stopping your cellphone from being used as a remote camera by your Windows PC altogether is easy. Open up the 'Manage mobile devices' window again, and slide the 'Enabled' slider to the left. You'll get a warning message about the loss of functionality, which you can dismiss to never see again. To turn it back on again, it's just a case of sliding the switch the other way. ⏻

LAB NOTES

ZAK STOREY, CONTRIBUTOR

The death of balance

Social media has killed the internet



This guy knew what was up.

SOCIAL MEDIA has warped our perspective. It was when the platforms transitioned away from chronological feeds to curated timelines. From a business perspective, it was a masterstroke: control what your users see, feed them what they 'like' so they stay for longer, and show them more ads, which you can force companies to pay for. It doesn't matter if Aunt Cathy's had a new baby; check out this *Warhammer* meme!!

As our world became more turbulent, these algorithms had a net negative effect. Entire communities and friendships were almost held up by social media. In any normal society, that would mean communication, debate, and discussion. Conversations on different ideas, perceptions, and thoughts challenged. By its very nature, that leads to growth, understanding, and empathy.

What the algorithms took away was the opportunity for that to occur. Instead, you were funneled into an echo chamber of like-minded people, telling you the same thing you believe. The problem is that it amplified those opinions. Minor irritants became exacerbated problems; narcissistic sensibilities and arguments exploded. I think we all know someone we no longer speak to because their opinions have become so unhinged.

Then TikTok arrived, and YouTube Shorts, Instagram Reels; mini continual dopamine hits. The same algorithms were applied. You can even game it and force them to show you all manner of random nonsense without interacting or liking anything. Watch a flat-earther video long enough, read the comments, and soon enough your entire feed will be a deluge of podcasts and YouTubers telling you about the firmament and sun simulator machines while dodging paid trips to the Antarctic Circle.

Once a long-winded joke, it's now gathered an almost cultlike status. The number of comments are increasing. But it's not just limited to that; any topic you can think of is now like this, and with it, greater biases and arguments are blowing up. This extremism on everything, from political to religious to scientific to technological to economics—all of it is reaching a fever pitch. Certain bad actors are, of course, cashing in on that, one way or another, and in turn actual truth, fact, and reason are almost lost in the screaming.

JEREMY LAIRD

Contributor

After the debacle of crashing 13th and 14th gen CPUs came the disappointment of Arrow Lake's gaming performance. Intel just can't get anything right at the moment, and I'm not sure the latest mea culpa from Chipzilla changes that.

Robert Hallock, Intel's Vice President and general manager of Client AI and Technical Marketing, said, "The performance we saw in review—and to be very clear, through no fault of reviewers—was not what we expected and not what we intended. The launch just didn't go as planned."

Apparently, Intel has a fix. "We identified a series of [multifactor] issues. They're at the OS level, they're at the BIOS level," he says.

Personally, I doubt Intel will be able to do much. I'd wager a chunk of what's holding Arrow Lake back is having the memory controller on a different die from the CPU cores, and that's not something you fix with a patch. Of course, AMD takes the same approach, but then it has been doing so since the Zen 2 back in 2019.

AMD has been optimizing that chiplet memory controller architecture for three generations. What's more, for games, AMD has its X3D chips with huge slabs of cache memory to directly mitigate the problem. Long story short, don't bet on Arrow Lake turning into a gaming beast any time soon.

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Does anyone really want to pay over $1,000 for a 1440p gaming panel?

Editor's Pick: Sony INZONE M10S

Does this represent value for money?

$1,100 FOR a 1440p panel? Really? Yes, really. May we present the INZONE M10S, Sony's foray into the 27-inch gaming OLED segment.

This monitor adopts stratospheric market positioning courtesy of the same LG-sourced 480Hz WOLED panel as the Asus ROG Swift PG27AQDP. It's the latest OLED technology from LG with Micro Lens Array enhancement. It's as bright as they come, with 275 nit full-screen SDR and up to 1,300 nits HDR.

Other specifications are as you would expect from a cutting-edge OLED gaming screen. Color coverage comes in at 98.5 percent of DCI-P3, and the pixel response is rated at a ridiculously fleeting 0.03ms.

Combined with that turbo-charged 480Hz refresh, you have the makings of a rather nippy gaming display. This is, of course, the point of the Sony INZONE M10S. Sony says optimal online shooter performance is the number one priority.

That extends to a 'tournament-compliant' 24.5-inch mode that operates at native 1332p resolution. You end up with black bars around the smaller 24.5-inch active area of the panel. It's unlikely you'd want to use it outside a tournament. Even then, standardized screens are provided.

Aside from speed, the other major selling points are design and engineering. The aesthetics are slick and minimalist, but it's the small stand that, well, stands out. You'd think the merest prod would have it toppling over, but it's actually very stable. It also offers tilt, height, and swivel adjustment, but no pivot into portrait or even fractional pivot adjustment.

As for connectivity, you get a pair of HDMI 2.1 sockets and a USB-A hub, but no USB-C connectivity, which is very stingy, given the price. That said, the eye-catching connectivity metric is surely DisplayPort 2.1 support. Only AMD's latest Radeon RX 7000 GPUs support DP 2.1, which means no Nvidia GPU is currently compliant.

However, the Sony INZONE M10S only supports the base UHBR10 DP 2.1 spec, which translates into a peak 40Gbps of bandwidth and 38.69Gbps of usable bandwidth. That's well below the 80Gbps and 77.37Gbps of the top UHBR20 DP 2.1 spec. Anyway, the consequence is that display stream compression or DSC is required to hit the full 480Hz. For our money, that's fine. DSC is visually lossless, and doesn't add latency, but it's used here.

But what of my impressions of this screen? It has a matte anti-glare coating, which probably suits the esports remit, but arguably attenuates the sense of eye-searing HDR sizzle by a fraction. Moreover, it's quick. It looks and feels slick even when jiggling application windows around on the desktop. In game? *Counter-Strike 2* is my multiplayer mayhem of choice, and if I've seen it in sharper, clearer, lower-latency rendition, I can't recall when.

Is this really the kind of display serious esports aficionados would go for? Or would they default to a 24-inch TN panel with even higher refresh? If the latter, who can justify this 1440p monitor's price tag?

That's the problem. As a general gaming monitor, let alone an all-purpose work-and-play panel, does a 1440p model for over $1,000 make sense? Remember, the new LG UltraGear 32GS95UE, a 32-inch 240Hz WOLED 4K model with an alternate 480Hz 1080p mode, can be had for exactly the same money.

Ultimately, if it's a 27-inch 1440p panel you desire, this should be near the top of your list. But if you want the best gaming experience for in excess of $1,000, there are far more impactful and multi-talented options available. **–JL**

$1,099, www.sony.com

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Reviewed...

74 Intel Core Ultra 9 285K

76 Intel Core Ultra 5 245K

78 Asus ROG Maximus Z890 Hero

80 HP Omen 17

82 Netgear Nighthawk RS300

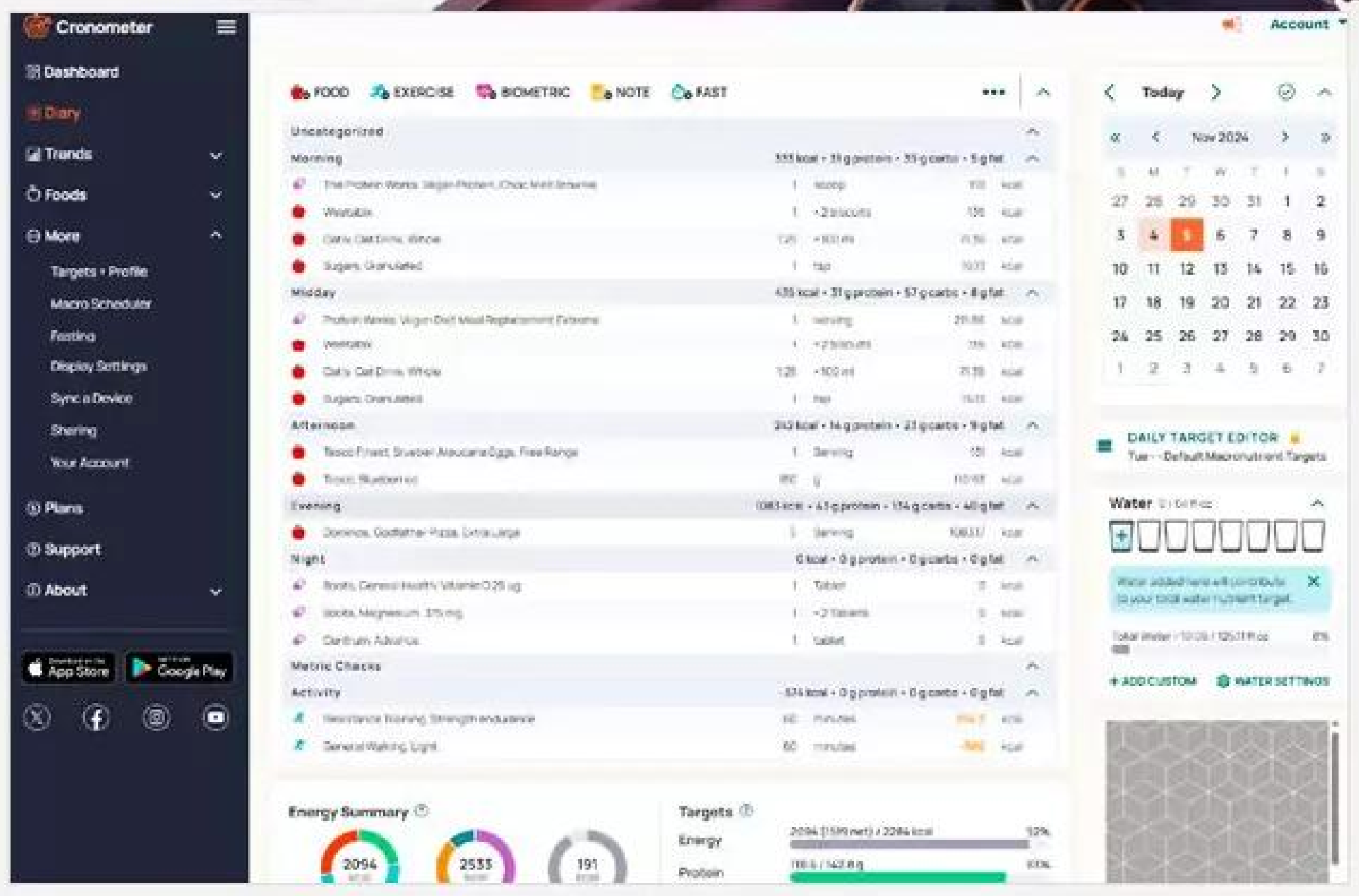
84 Acer Swift 14 AI

87 Razer Kraken V4 Pro

88 Razer Freyja

89 Goemetric Future Model 5

90 Dragon Age: The Veilguard



92 MyFitnessPal vs Cronometer

Intel Core Ultra 9 285K

Designed by Intel, made by TSMC, a match made in heaven?

THE CORE ULTRA 9 285K, the new flagship CPU showcasing Intel's latest Arrow Lake architecture, marks the start of a brave new era for Intel. A big slab of silicon, containing all the cores and sundry? Gone. Manufactured on the latest Intel process node? Also gone.

Oh, and class-leading gaming performance? Turns out that's gone, too, even according to Intel's own numbers, which is arguably the most conspicuous loss. Hold that thought—what you do get is the same use of mostly TSMC-made chiplets that were first introduced with the Meteor Lake mobile chip. So, does that make for a better flagship CPU than something made purely by Intel itself?

For gaming, the answer is no. In terms of average frame rates compared to the old Core i9-14900K, the Core Ultra 9 285K is 12 percent slower in *Cyberpunk 2077*, 9 percent slower in *Baldur's Gate 3*, 3 percent slower in *Metro Exodus*, and 15 percent slower in *Warhammer 3*. It's also 23 percent slower in the Factorio test.

It's the same pattern versus the Core i7 14700K, AMD Ryzen 9 9950X, and 9900X. Other than the odd case where a 1 percent low value favors Arrow Lake, Intel's new processor is notably slower than Intel's own Raptor Lake and AMD Zen 5 in gaming—and Zen 4, for that matter.

On the upside, Arrow Lake merely sips at power during gaming. With an average package power consumption of just 83W in *Baldur's Gate 3*, the 24-core Ultra 9 285K uses less energy than a six-core Ryzen 5 9600X. That's impressive.

Of course, the world of desktop CPUs is more than just gaming, so some of this could be forgiven if the Core Ultra 9 285K ruled the roost in content creation, rendering, and office productivity. Starting with Cinebench 2024, the Core Ultra 9 285K showcases just how much progress Intel has made in improving its cores, especially the E-cores.

The fact that the new chip outperforms the 9950X and 14900K with fewer threads is remarkable. In the multithreaded test, the 285K is 4 percent faster than the 9950X and 29 percent better than the 14900K. The 285K also uses 16 percent less power than the 14900K, although it does use 7 percent more than the 9950X. In terms of power efficiency, that means that AMD's flagship chip is still the best for this kind of workload, but the 285K leaves the 14900K far behind.

While the good news continues across the rest of our content creation tests when comparing Arrow Lake to Raptor Lake, the Core Ultra 9 285K is notably behind the Ryzen 9 9950X in Blender, 7zip compression and decompression, and Handbrake video encoding.

For all of Arrow Lake's strengths, then, if you already have an Intel 13th or 14th Gen PC, or AMD AM5 setup, there's nothing here to make it worth jumping platform. If you have a much older PC, the performance is good enough to warrant considering a Core Ultra Arrow Lake upgrade instead of a Raptor Lake one. Yes, the latter is a better gaming processor, but it achieves that in part through a hefty energy demand, which in turn results in a very toasty processor.

The Ultra 9 285K uses relatively little power, and it's very easy to cool—for gaming, at least. But is anyone going to spend $586, plus several hundred more on a new Z890 motherboard and DDR5 RAM kit, just for lower power consumption? The simple truth is that if energy consumption was a major concern, an AMD Zen 5 Ryzen setup would be the obvious choice.

Overall, the Core Ultra 9 285K isn't actually a bad CPU. Its performance is relatively near the competition, and Intel, with TSMC's help, has done well to reach that low power consumption in games. But paying a top-tier price for second-tier performance doesn't make sense when there are plenty of other options to choose from. **–NICK EVANSON**

VERDICT **7**

Intel Core Ultra 9 285K

+ CORE COMPETENCE Low power consumption in games; Strong multithreading.

− CORE MELTDOWN Slower in games than Raptor Lake, Zen 5; Quite expensive.

$589, www.intel.com

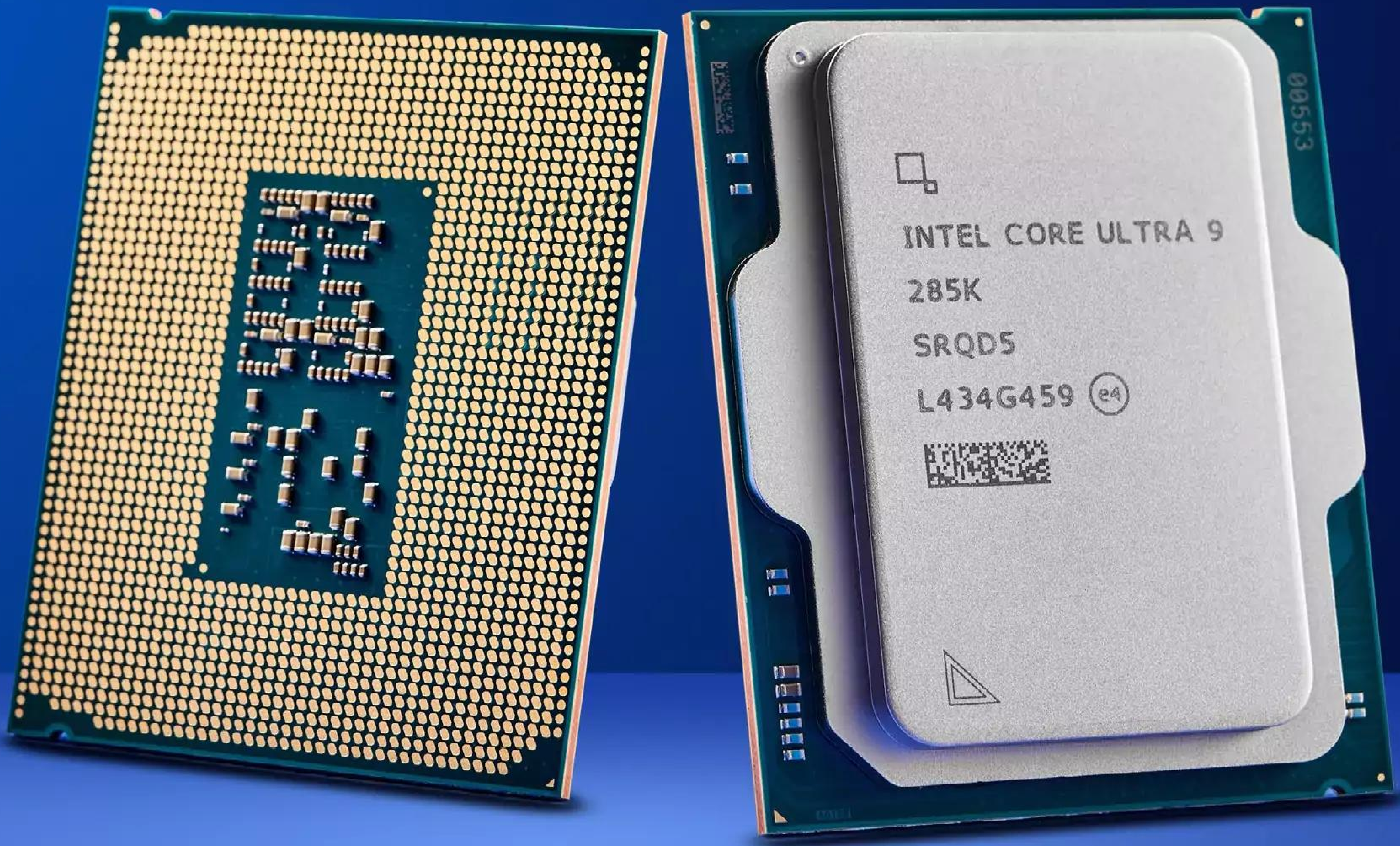
BENCHMARKS

	Intel Core Ultra 9 285K	Intel Core i9-14900K	AMD Ryzen 9 9950X
Cinebench 2024.1.0 (points)	**2390**	2044	2290
Blender (samples/min)	169	149	**197**
Total War: Warhammer III (fps)	139	164	**170**
Cyberpunk 2077 1080p (fps)	103	**118**	114
Baldur's Gate 3 (fps)	94	**109**	106
Average power consumption (rendering; W)	210	248	**196**

Best scores are in bold.

SPECIFICATIONS

Cores (P+E)	8+16
Threads	24
Base clock	3.7 GHz (P-core)
Boost clock	5.7 GHz (P-core)
L3 Cache	40 MB
L2 Cache	36 MB
Unlocked	Yes
Max usable PCIe lanes	24
Graphics	Intel Graphics (4 Xe cores)
Memory support (up to)	DDR5-6400
Processor Base Power (W)	125
Maximum Package Power (W)	250


INTEL CORE ULTRA 9
285K
SRQD5
L434G459 e4
00553

Intel's new chiplet CPU architecture is radical, but is it any good?

INTEL CORE ULTRA 5
245K
SRQCT
L434G499

Intel's new chiplet tech is actually produced mostly by Taiwanese foundry TSMC.

Intel Core Ultra 5 245K

Can Intel compete in the budget CPU battle?

THE LAUNCH OF ARROW LAKE marks a new chapter in Intel's history. This is the first desktop processor in its ranks that isn't made by Team Blue itself. The multi-tile design, first introduced with Meteor Lake in the mobile sector, is predominantly manufactured by TSMC. Only the base tile and packaging are handled by Intel.

The Core Ultra 5 245K (and the GPU-less 245KF) is currently the baby of the Arrow Lake line-up, and it's basically a Core Ultra 9 285K with two P-cores and eight E-cores disabled. The clocks are a little lower, too, and there's less L3 cache, all of which reduces the maximum power limit to 159W.

While it's an obvious successor to the Core i5 14600K, the 245K's $309 MSRP puts it closer to the Ryzen 7 9700X than the Ryzen 5 9600X (currently $249 and $327 on Amazon, respectively). Architecturally, though, it's very different to both, as AMD's chips are six/eight-core processors, with support for 16 threads, while the Arrow Lake chip has 14 cores and 14 threads.

One further processor that the Core Ultra 5 245K is close to price-wise is the Core i7 14700K. That 20-core chip can be picked for around $50 more than the new Arrow Lake—just 14 percent more expensive, but with twice as many threads on offer.

In fact, in our testing, the CPU with the closest matching performance is the Ryzen 5 7600X, a processor that has fewer cores and threads, lower clocks, and launched over two years ago. Moreover, while the 245K is on par with the 14600K in *Homeworld 3* and *Metro Exodus*, it is noticeably worse in all the other game tests—15 percent slower in *Cyberpunk 2077* and *Warhammer 3*, and 12 percent slower in *Baldur's Gate 3*. Ouch.

Where the Core Ultra 5 245K does beat the competition is power consumption—using just 83W in *Baldur's Gate 3*, it uses 46 percent less energy than the 14600K and 24 percent less than the 9700X. Even though the gaming performance is worse, it's not 46 percent worse, and it's a near-miraculous achievement by Intel. Or should that be TSMC and its N3B silicon node?

In previous architectures, like Raptor Lake and Alder Lake, great gaming performance came at a cost of high power consumption, and this was an aspect that AMD had the measure of Intel in. Arrow Lake doesn't completely counter the power advantages that Zen 4 and 5 have, but it's a big step in the right direction.

The 245K is also much more impressive when it comes to content creation. For 3D rendering, design work, video editing, and all that stuff, the 245K is not only much quicker than the old 14600K—it has the measure of the AMD competition, too.

Summarizing the relative merits of the Core Ultra 5 245K versus the 14600K, then, is a straightforward affair. Gaming is poor, content creation is good, and power consumption is great. But Intel isn't the only company making desktop CPUs, and the summary also applies when comparing the 245K to the Ryzen 5 9600X and Ryzen 7 9700X.

The Core Ultra 5 245K isn't as disappointing as the flagship Core Ultra 9 285K model, but unless you specifically want an affordable processor purely for content creation tasks, or a low-power chip for an SFF build, Arrow Lake's appeal is limited. And while Intel is adamant that Raptor Lake's voltage problem has been fixed, they're somewhat hard to recommend too, even though they're much better in gaming than the 245K.

That's simply because the Ryzen 5 9600X is cheaper and performs well in games. If content creation is important, then the Ryzen 7 9700X is on par with the 245K, and only a few dollars costlier. Intel's Core Ultra 200S series aren't bad processors, and the Ultra 5 245K is perhaps the best of the lot right now. Yet, there are better gaming CPUs on the market for the same money from not only AMD, but even Intel. **–NICK EVANSON**

VERDICT

7

Intel Core Ultra 5 245K

➕ BULLSEYE Very low power consumption; Pretty good for content creation.

➖ OFF TARGET Slower in games than both Intel Raptor Lake and AMD Zen 5.

$309, www.intel.com

BENCHMARKS

	Intel Core Ultra 5 245K	Intel Core i5-14600K	AMD Ryzen 5 9600X
Cinebench 2024.1.0 (points)	**1484**	1352	911
Blender (samples/min)	**97**	93	70
Homeworld 3 (fps)	72	75	**81**
Cyberpunk 2077 1080p (fps)	99	**116**	107
Baldur's Gate 3 (fps)	86	**97**	92
Average power consumption (rendering; W)	122	178	**87**

Best scores are in bold.

SPECIFICATIONS

Cores (P+E)	6+8
Threads	14
Base clock	4.2 GHz (P-core)
Boost clock	5.2 GHz (P-core)
L3 Cache	26 MB
L2 Cache	24 MB
Unlocked	Yes
Max usable PCIe lanes	24
Graphics	Intel Graphics (4 Xe cores)
Memory support (up to)	DDR5-6400
Processor Base Power (W)	125
Maximum Package Power (W)	159

MAXIMUS
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REPUBLIC OF GAMERS

It might look pretty, but that price tag is a kicker.

Asus ROG Maximus Z890 Hero

All the ports for all the money

GAME FIRST WORK SECOND

WHAT AN ODD technological world we live in. It's one of the perks of a new generation of processors that we inevitably get new chipsets as a result. No matter whether those processors are backward compatible or not, the fact is that we'll almost always get a new range of motherboards to back them up. Seeing how each generation of board evolves and changes, and what connectivity is added or taken away, and of course the massive change in design aesthetics, is fascinating on many levels. For good folk like ourselves who dream of system builds almost nightly, how they look impacts our content plans and aspirations. There's an excitement around it.

Asus has pretty much always been at the top of the pile when it comes to top-quality motherboards. It's had a bit of dominance in the field, producing both insane-level products (sometimes too good—here's looking at you, Z690 overvolting), combined with exceptional BIOS access and intelligent UEFI design to back it up. They weren't always unreasonably priced, either. The 'Asus tax', as many dubbed it, clearly was there, but it was tolerable.

These days, though, we're in a whole other world of pain. Take this board, the Z890 Hero. It started out life at $700. That is phenomenally high, although we should probably be thankful, given it's the same price as the Z790 Dark Hero started out with (although that was a refresh board). At least we haven't seen a price hike. That's surprising, particularly given Z890 and its subsequent Core Ultra chips take advantage of a newer LGA1851 socket, among other new technologies.

From a generational standpoint, there has been some additional change here, too. We've gone from five M.2 slots up to six, with the split now being 3x 5.0 and 3x 4.0 (rather than 1x 5.0 and 4x 4.0), there are multiple USB C internal headers instead of just the one 20Gbps port, Asus has added a 5Gb Ethernet port on the rear, and the M.2 heatsink and mounting solutions have been vastly improved. We've also seen a large improvement to the power phase setup, going to a 22+1+2+2 phase design versus the 20+1+2 phase setup.

As for what's gone, comparing the two, the Z790 Dark Hero has one additional USB 10Gbps Type A port, and the full five-channel audio-out solution, while the Z890 Hero has the far simpler line out/mic in solution instead. Otherwise, wireless connectivity stays the same, with WiFi 7 and Bluetooth 5.4 on both.

There's a lot here, and it's actually a reasonable upgrade to its Z790 cousin, particularly as the RRP hasn't shifted. That said, the Dark Hero is now available for around $530, so it's better value.

This is a premium motherboard for connectivity, and it's got that Asus ROG aesthetic and brand behind it, but is it worth it? The fact that Asus's entire Z890 motherboard range (and remember, this is the entirety of this chipset) ranges from $230 all the way up to $1,000 is pure insanity. You can build a cheaper Z890 system, that's a given, but we're starting to question whether that price variance between the top and bottom is warranted for what's effectively a very large interconnect. **–ZAK STOREY**

VERDICT **9**

Asus ROG Maximus Z890 Hero

+ **THEMISTOCLES** Outstanding connectivity; Nice gen-on-gen upgrade; Brilliant aesthetic; Top-tier BIOS options; Insane RAM compatibility; Good software support (once it's installed); Best Wi-Fi implementation.

− **XERXES** | Pricing; Does require PCIe power to boot.

$700, www.asus.com

SPECIFICATIONS

Chipset/Socket	Z890 / LGA1851
Max Memory Support	192GB DDR5 @ 9200+
Storage Support	6x M.2 Slots (3x 5.0x4 and 3x 4.0x4), 4x SATA 6Gb/s
PCIe Support	1x PCIe 5.0 x16, 1x PCIe 4.0 x16, 1x PCIe 4.0 x1
Form Factor	ATX, 12 x 9.6-inches
Rear I/O	2 x Thunderbolt 4 USB Type-C ports, 5 x USB 10Gbps ports (4 x Type-A + 1 x USB Type-C), 4 x USB Type-A 5Gbps ports, HDMI, WiFi 7, 2.5Gb Ethernet, 5Gb Ethernet, 2x Gold-plated audio jacks, Optical S/PDIF out, BIOS FlashBack, Clear CMOS

HP Omen 17

When getting the job done isn't good enough…

I SAY IT EVERY TIME: this range of HP Omen gaming laptops will always have a special place in my heart. My very first rig was an RTX 1050 HP Omen 15, in all its chunky metallic glory. But the 2024 HP Omen 17 is a whole different ball game. Yes, it's still a hefty, 17-inch device, but gone are the red accents, textured lids, and angular decals. Instead, this slab of black plastic prioritizes performance over flashy external sing-song.

Marrying an 8000-Series AMD processor with an Nvidia RTX 4070 GPU, it's just on the cusp of mid-range, offering big-screen play without the price tag of most 18-inch devices. The affordability is reflected by the all-plastic construction, though considering you can easily spend over $2,000 on a mid-range configuration, a little alloy wouldn't go amiss.

Still, it's put together well enough, and feels solid. With that comes a 6.4lb, 1.18-inch thick form factor that's certainly taller than the Alienware M16 R2 (0.93-inch) and Acer Nitro 16 (0.98-inch). Of course, like most big-screen gaming laptops, this isn't designed for portability.

There are a number of configurations, but for now, they all pair AMD's 8000-series CPUs with Nvidia's entry-level and mid-range graphics cards. In this case, you're getting an AMD Ryzen 7 8845HS, Nvidia RTX 4070, 16GB DDR5 RAM, 1TB SSD, and FHD 144Hz display. It's a middle-of-the-road setup, but it still comes in over $2,000 at full retail price.

That LCD screen is the weakest link in the chain. Only 1080p, it's nowhere near as bright as the one on the Acer Nitro 16. The colors pop, but it's nothing like an OLED HDR experience. The keyboard is another story. With very low-key travel, an echoey feel, and a slightly sloppy debounce, this is not a deck worthy of a gaming laptop at over $2,000 MSRP.

I'm not saying a keyboard has to reach the super-snappy heights of the mechanical switches featured in many Alienware laptops, but the majority of machines I've tested have offered far more tactility under the fingertips. The trackpad is still more than serviceable, though, and remains nicely responsive with a large base.

Most of the Omen's ports are located to the rear of the machine—a win for anyone looking to keep their setup free of cable webs—but there are a few sacrifices here as well. There's only one USB-C option on the whole device and it doesn't support Thunderbolt, given the AMD platform. You'll still find three USB-A ports (two on the rear and one of the right panel), as well as an Ethernet RJ45, HDMI 2.1, and 3.5mm audio.

Strangely for a machine that's looking more geared towards staying at home, the HP Omen 17 does pack a pretty impressive battery life. HP rates it at five hours on a single charge—fantastic for a gaming-specific rig. I managed to swing around two to three hours of gaming on balanced power presets, something I could never dream to achieve on other machines. How much you'll really put that battery to the test considering the size and weight of the Omen is another matter.

As for gaming performance, this the second highest-performing RTX 4070 gaming laptop I've tested yet, scoring over 60fps in every test. That's a solid backbone to work with, proving the competitive edge to that larger chassis and additional cooling space. There's performance to spare at the system's native 1080p, that's for sure.

All of this means the HP Omen 17 bleeds that RTX 4070 dry. Very little performance is left on the table. What you don't get is a particularly sleek chassis, an exceptional feature set, or even a terribly good screen. –**TABITHA BAKER**

VERDICT

6

HP Omen 17

+ AUGURS WELL Solid chassis; Squeezes its GPU for every possible frame rate.

− ILL OMEN Mediocre screen; Thick chassis; Short on features.

$2,099, www.hp.com

SPECIFICATIONS

Display	17.3-inch 1080p 144Hz
Processor	AMD Ryzen 7 8845HS
GPU	Nvidia GeForce RTX 4070
RAM	16GB DDR5 5600MHz
Storage	1TB PCIe Gen4 NVMe M.2 SSD
Connectivity	WiFi 6, Bluetooth 5.3
Ports	2x USB Type-A 10Gbps, 1x USB Type-A 5Gbps, 1x HDMI 2.1, 1x 3.5mm, 1x RJ-45, 1x USB Type-C 10Gbps (Power Delivery, DisplayPort 1.4)
Dimensions	1.18 x 15.65 x 10.94 inch
Weight	6.4lbs (2.88kg)

BENCHMARKS

	HP Omen 17	**Acer Nitro 16 (RTX 4070)**	**Alienware M16 R2 (RTX 4070)**
Shadow of the Tomb Raider (1080p, high -fps)	148	146	**161**
Total War: Three Kingdoms (1080p, high -fps)	127	124	**137**
Returnal (1080p, high -fps)	73	**96**	71
PC Mark 10 (1pts)	**7,781**	6,627	6,855

Best scores are in bold.

© UNSPLASH

HP's 17-inch gaming portable is solid enough, but not exactly a looker.

Netgear Nighthawk RS300

High-speed Wi-Fi 7 at a competitive price

NETGEAR'S RANGE of Wi-Fi routers and mesh systems are always well-designed and offer high-end performance for business and home users who need a fast, reliable Wi-Fi connection. They do tend to be pretty expensive, though, as we saw with the recently-launched Nighthawk RS700 (reviewed in our March issue), which weighed in at a hefty $700.

That's a lot of money for a single, standalone router—especially for home users who probably don't need the blazing 19Gbps Wi-Fi speed offered by the RS700. The new Nighthawk RS300 is therefore designed to provide a high-speed Wi-Fi 7 upgrade with a more affordable price tag. As you might expect, the RS300 is slower, offering a top speed of 9.3Gbps, but that's still more than fast enough to handle gaming, streaming 4K video, and other demanding online tasks, and it costs just under half the price of the RS700.

The design of the RS300 is similar to that of the high-end RS700, with both models adopting a tall, obelisk shape and finished in matte black. However, the lower price of the RS300 means that its plastic casing doesn't feel quite as sturdy as its high-end counterpart.

Still, the RS300 provides a 2.5 Gigabit Ethernet port that can handle high-speed fiber internet connections. There are two more 2.5 Gigabit ports to provide high-speed wired LAN connections for devices, such as laptops and desktops which need the best performance for gaming or streaming 4K.

For more routine tasks, such as web browsing and email, the router also provides two conventional Gigabit Ethernet ports as well. And, unlike some less expensive routers, the RS300 also includes a USB port that will allow you to connect a USB storage device and share files with other people on your network. I also like the LED status lights on the front panel for all of these ports. These let you see that everything is working properly at a glance, without having to check the Netgear app.

SPEED NEEDS

The RS300 supports tri-band Wi-Fi 7 with a top speed of 9.3Gbps. That's a pretty modest speed for Wi-Fi 7, but it should be more than adequate for most home users, and even quite a few small businesses, too. The router creates a single network that merges the three frequency bands—2.4GHz, 5.0GHz, and 6.0GHz—and automatically connects your devices to the fastest band that's available in that particular room or location. Some advanced users might prefer more detailed controls within the app, such as the ability to create separate networks using each frequency band, but that's available on the high-end RS700.

There are also very few parental controls included. Netgear attempts to 'upsell' you with subscription services, which is irksome. But we can't fault the actual performance of the RS300. Our office internet connection provides a top speed of 150Mbps, but our aging router can only manage around 120Mbps for the Ookla Speedtest, while game downloads from Steam struggle along at around 100Mbps. We also have an office at the back of our building where the Wi-Fi signal from our normal router can barely reach, forcing us to rely on a set of wired Powerline adaptors to provide a decent internet connection.

The RS300 solved all our Wi-Fi problems straight away, immediately hitting 150Mbps for devices in the same room for both Steam downloads and the Ookla Speedtest. It had no trouble zapping its Wi-Fi signal along our L-shaped corridor to reach that back office, either. As I walked along the corridor with my laptop, I was pleased to find that the RS300 maintained that 150Mbps speed.

Larger homes or offices might need a mesh Wi-Fi system, of course. But most home users and small businesses will find that the Nighthawk RS300 provides a high-speed Wi-Fi 7 upgrade with one of the most competitive prices we've seen so far. **–CLIFF JOSEPH**

VERDICT
8

Netgear Nighthawk RS300

+ NIGHT RIDER Strong Wi-Fi 7 performance; Competitive price; 2.5Gb Ethernet.

− LOST IN THE DARK Wi-Fi 7 is still fairly expensive; Some features require additional subscriptions.

$329, www.netgear.com

SPECIFICATIONS

Wi-Fi	Tri-band Wi-Fi 7 (2.4GHz, 5.0GHz, 6.0GHz)
Wi-Fi Speed	9.3Gbps
Ports	1x 2.5Gb Ethernet (WAN), 2x 2.5Gb Ethernet (LAN), 2x Gigabit Ethernet (LAN), 1x USB-A (3.0)
Processor	Quad-core 2.0GHz
Memory	2GB RAM
Storage	512MB NAND Flash
Dimensions	9.8 x 5.9 x 4.0in
Weight	2.09lbs

The low-profile, winged 'shuttle-craft' design that Netgear used for several years is now a goner.

Arm is once again one step closer to taking over the world.

Acer Swift 14 AI

A true battery life king

WE MAY HAVE SLIGHTLY teased this particular laptop in last month's issue with our Acer Swift Go 14 review. If you'd glanced down that article's benchmark sheet, there should have been one big figure that stood out to you perhaps more than most. Yep, we're talking about the battery life on this little number, because, well, it's absolutely insane.

That's not a typo; that's not a benchmark testing error; no, it's far more than that. It's a score of over 26 hours in a battery benchmark test. To be more specific, the Swift 14 AI ran a continuous video loop at 50 percent screen brightness for over a day. It was so radically superior to every other test we've performed that we actually ran it multiple times, each test coming to the same conclusion. This thing is a goliath when it comes to battery endurance.

Why is that, then? Simply put, the Swift 14 AI is taking advantage of two intelligent design decisions to make that happen. First and foremost, it's utilizing Qualcomm's latest Snapdragon X Plus processor, and secondly, it's got one of the largest internal batteries we've seen in a laptop at this form factor, combined with a comfortable lower-resolution screen. All of that adds up to some insane long-term longevity in these tests.

The processor in question, the Qualcomm Snapdragon X Plus X1P-64-100, is on the 'slower' side when it comes to Qualcomm's latest Arm arsenal. It packs in 10 cores, 42MB of cache, and an effective clock speed of just 3.4GHz. There's no boost frequencies here, unlike that within the Snapdragon X Elite found inside of Asus' Vivobook S 15, and what that means is that power draw is far far lower, particularly as it lacks an extra two cores. That brings temperatures down along with it. Combine that with an extra 5 WHrs in the battery department, and what you're left with is an absolute unit when it comes to daily work.

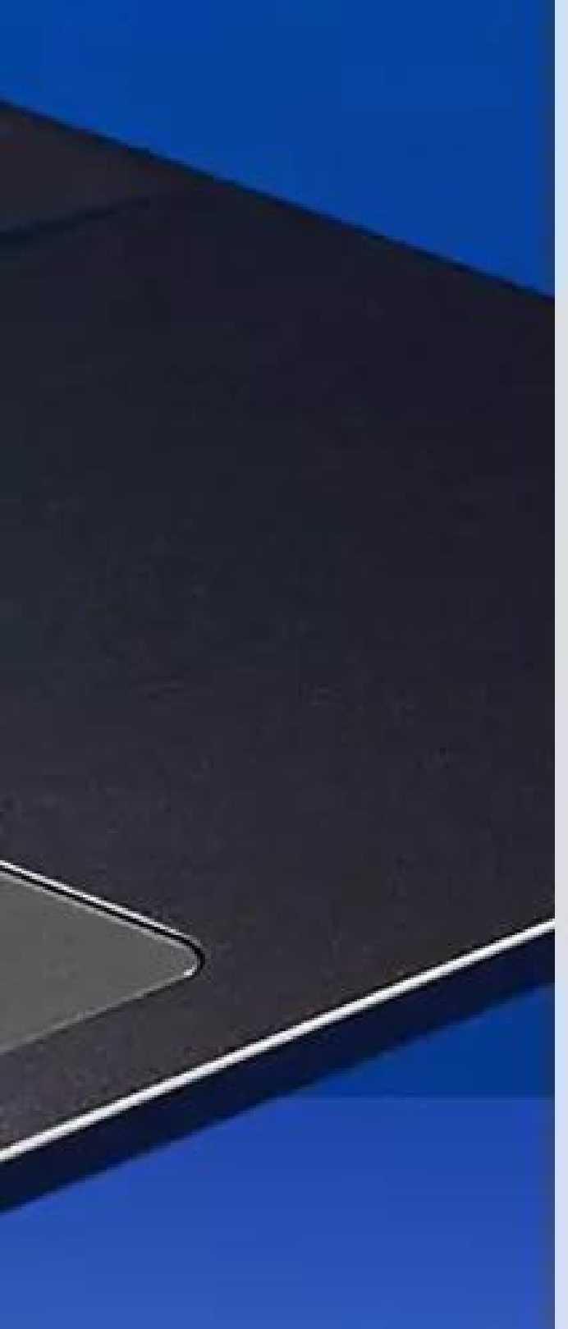
PERFORMANCE

Impressively, that doesn't actually impact performance as heavily as you'd expect. In the realm of portable notebooks, that X Plus still delivers 742 points in Cinebench 2024's multi-core test and 107 in its single-core (actually beating that X Elite in testing on the single core figure). Acer has also paired it with one of WD's SN5000S OEM PCIe 4.0 drives, giving it some seriously impressive sequential and random 4K performance.

In games, it does struggle a touch. At 1080p on medium graphical presets, it performs solidly in the likes of *Cyberpunk* (with a little help from FSR and AI frame gen), but it does struggle in more CPU-dominant games like *Final Fantasy*, as it lacks that poppy single-core grunt so synonymous with the world of MMOs, or at least compared to the competition.

Specs aside, the overall build quality is top-tier. It's a simple chassis and somewhat plain design. You get a satin gunmetal finish, a simple keyboard, and some very basic Acer logos, and that's about it. Ports are sound as well, with twin USB 4.0 Type C ports, along with dual 3.2 Type A, WiFi 7, and Bluetooth 5.4 built in as standard. Plus, you get a beautiful 2560x1600 IPS 90Hz screen that, although not as color-rich as an OLED display, does deliver a pixel density of 208.20 overall, far greater than even the best 27-inch 4K desktop solution.

All of that is available for just $1,050 off the shelf. It may not be the most outlandish or prettiest thing in the world, and yes, performance isn't absolutely mind-melting, but the value per dollar you're getting here is second to none, and to finally have a work notebook that can last well over a day without taking a charge is just a joy to behold. **–ZAK STOREY**



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BENCHMARKS

	Acer Swift 14 AI - SF14-11-X6YU	Acer Swift Go 14 - SFG14-73	Asus Vivobook S 15 - S5507
Cinebench 2024 Multicore (Index)	742	636	**925**
Cinebench 2024 Single Core (Index)	**107**	99	106
CrystalDiskMark C: Sequential Read / Write (MB/s)	**6,381 / 5,739**	4,765 / 3,503	5068 / 3,621
CrystalDiskMark C: Random 4K Read/Write (MB/s)	**94.42 / 245.89**	66.43 / 227.22	69.82 / 210.87
Cyberpunk 2077 FSR @ 1080p Medium (Avg Fps)	**39.6**	29.3	25.1
Final Fantasy XIV FSR @ 1080p Medium (Avg Fps)	35.9	**40.8**	37.3
3D Mark Solar Bay (Index)	9,945	**11,644**	10,027
3D Mark Steel Nomad Light (Index)	1,970	**2,943**	1,964
Steel	25,235	**25,914**	25,496
PC Mark 10 Battery Test - Video (Minutes)	**1,573**	361	725
Battery Size (WHr)	**75**	65	70
Price (USD)	$900	$720	$1000

Best scores in bold. All tests performed with a clean install of Windows, with the latest updates and drivers. Games tested at 1080p on the medium graphical preset. Cyberpunk does not have ray tracing enabled. Battery benchmark performed at 50% screen brightness. Prices correct at time of writing.

VERDICT
9
KICK ASS!

Acer Swift 14 AI

➕ **SWIFT PRECISION** Next-level battery life; Incredible bang for the buck; Beautiful display; Solid build quality.

➖ **A SWIFTY** Finish could be better.

$1,050, www.acer.com

SPECIFICATIONS

CPU	Snapdragon X Plus X1P-64-100 @ 3.4 GHz
GPU	Qualcomm Adreno
RAM	16GB LPDDR5X @ 8488 MT/s
Storage	1TB M.2 PCIe 4.0 SSD
Screen	14.5-inch 2560 x 1600 - IPS @ 90 Hz
Connectivity	2x USB 4 Type C, 2x USB 3.2 Type A, 1x Headphone Jack, WiFi 7, Bluetooth 5.4
Battery Capacity	75WHr
Dimensions	12.7 x 8.9 x 0.6 inches
Weight	2.94 lbs

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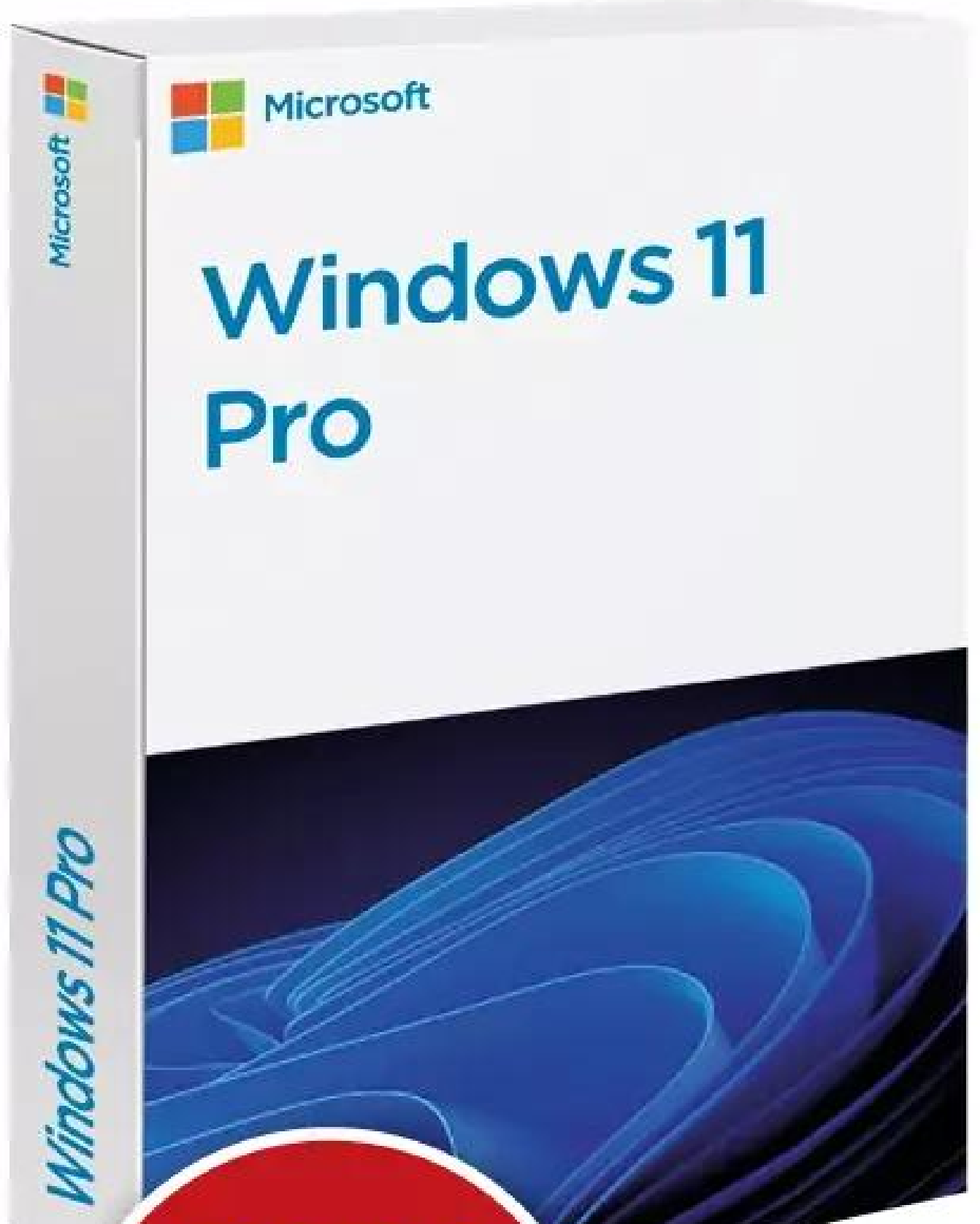

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software.maximumpc.com

Razer Kraken V4 Pro

Razer's pricey new headset majors on haptics

THE RAZER KRAKEN V4 Pro doesn't hide its premium nature. This haptic-focused headset sits behind a massive $399 price tag, putting the $349 SteelSeries Arctis Nova Pro Wireless and $379 Astro A50 X in the firing line. This is a slimmer design compared to the Razer Kraken V3 Pro. It's not the obnoxiously wide headset you may have seen in the past, but the Kraken V4 Pro still retains its recognizable form factor. The cup cushioning itself has been elongated to sit around the ears rather than directly on top. That generous padding sits along the headband, too.

Of course, let's not forget that blazing RGB on the side. It's easily switched off if you're in a more focused setting, but even switched on, it's a subtle effect. More significant, then, is the Sensa HD haptic technology. The vibrations are designed to recreate sensations via dynamic rumbles, changing speed, intensity, and direction based on your in-game actions.

This is haptic technology that completely separates itself from audio (unlike Razer's previous iterations), though where games don't have Sensa support, you'll still be able to feel that rumble through the game's sound as well. At the moment, the brand's list of supported games is fairly humble, but it includes big hitters like *Hogwarts Legacy*, *Final Fantasy XVI*, *Silent Hill 2*, and *S.T.A.L.K.E.R 2*, and is set to continue growing as well.

There's a good degree of control over just how these haptics function in the Razer Synapse 4 app as well, plus three haptic modes accessible via the OLED base station, the latter offering a tactile dial for adjusting various settings plus two USB ports. The mic, meanwhile, hides away in the main cup when not in use, and you'll find both Bluetooth and 2.4GHz on as standard, plus USB and a 3.5mm jack with dual simultaneous connection. That means you can run music from one device and your game audio from another directly through the headphones.

As for battery life, the Razer Kraken V4 Pro can run for up to 50 hours with no haptics or RGB, beating the Astro A50 X's 24 hours and the SteelSeries Arctis Nova Pro Wireless's 22 hours. But what of sound quality? The headset itself sounds great, with strong attention to directional detailing in competitive pursuits like *CS:2* and *Apex Legends*.

Mid-tones are slightly clustered in *Horizon Forbidden West*, with the metallic clanking of machines overwhelming the audio range and losing their own details. That stuffy mid-range can be teased out by tinkering with EQ settings in Synapse, but it still feels too close of a soundstage to compare with the SteelSeries Arctis Nova Pro.

Doom Eternal was a delight, however, with that rumbling bassline tracking beautifully across haptics, adding an extra sense of grunt to more chaotic battle scenes. Higher ranges also peeked through here, with satisfying clinks and chimes whenever I grabbed a pickup. The overall soundstage feels a little more cramped than that of the Nova Pro Wireless and Astro A50 X.

Then we get to the haptics. Razer's Sensa HD tech promised directionality and detail, and I don't see enough of that in day-to-day play. Set to only take haptic feedback from audio, explosions and more impactful soundtrack moments play out with a satisfying punch. But I couldn't see how to run both audio-to-haptics and Sensa HD at the same time. When I switched to Sensa, I lost almost all my haptic feedback in many games.

That said, I prefer the Kraken V4 Pro for music. Not every song benefits from haptic feedback. In fact, more mellow tracks do better with those motors switched off. However, bold basslines and brash drum beats feel incredible. If you like music that leans toward the lower ranges, then, you'll have a particularly good time here. **–TABITHA BAKER**

VERDICT
7

Razer Kraken V4 Pro

➕ **TOUCHY FEELY** Powerful haptic feedback; Robust audio quality; Slimmer design.

➖ **STOP TOUCHING ME** Mid-range feels clustered; Limited haptic support; Expensive.

$399, www.razer.com

SPECIFICATIONS

Connection	2.4GHz / Bluetooth, wired (USB-C / 3.5mm)
Drivers	Razer TriForce Bio-Cellulose 40mm
Frequency response	20Hz - 28kHz
Microphone	Retractable HyperClear Super Wideband
ANC	None
Controls	Volume, mic mute, multi-function button, haptics
Battery	Up to 50 hours
Weight	14oz (397g)
Compatibility	PC, PlayStation, Nintendo Switch, mobile

Razer Freyja

Whole-body haptic feedback at a premium price

SINCE NINTENDO first released the RumblePak for the N64 back in 1997, haptic feedback has become a standard feature of game controllers. Nowadays, you can also get headsets that rumble to increase the immersion, so it was only a matter of time until the tech made its way into a chair, giving you whole-body feedback, rather than just through your head and hands.

Razer is at the forefront of this feedback revolution, thanks to its Sensa technology, which features on its Razer Kraken V4 Pro (reviewed on the previous page). It's also what powers this Freyja, which isn't actually a gaming chair, but a cushion that sits over your existing seat of choice. It's perhaps not the most elegant solution—that would be a chair with everything built in, but until that arrives, this is a kind of toe-in-the-water test case from the US-Singaporean gaming lifestyle brand.

Installation was simple, and we found the cushion nestled neatly into both of our office chairs. It looks and fits better into a gaming chair like the noblechairs Legend (reviewed in our February 2023 issue), than it does a traditional office chair like Ikea's ubiquitous Markus. Adjustable straps go around the bottom and shoulders of the chair to secure it in place, and the good news is that it's comfortable to sit on even when not in use, and it is quick to remove if you want to.

Razer has made the slightly confusing design choice to create a cushion that needs to be plugged into the wall for power, but also needs a HyperSpeed wireless dongle for communicating with your PC. This is slightly annoying, as the power cable is quite short. Perhaps a single, long USB cable for data and power wouldn't provide enough juice to make this thing work, which is a shame. A battery pack would have been the most elegant solution, but again, perhaps this wasn't technically possible.

Once you're set up, you need to install Razer's Synapse 4 software in order to set up the cushion's features. There's a lot of granularity to the vibration controls, and it's easy to balance the level of vibration from the six feedback zones so that they pack a punch but are still comfortable.

By default, the cushion will monitor the audio generated from your PC and use the low-level frequencies to provide haptics. It works well, and after an initial period of getting used to the sensations, it's actually weirdly satisfying. I'm assuming that not many people are going to use this during the work day, but what you get up to in the privacy of your own home is up to you, I guess.

GAME ON

The chair really comes into its own on supported games, of which the list is quite short at the moment, but there are some big hitters, like *Final Fantasy XVI*, *Hogwarts Legacy*, and *Silent Hill 2*. You can really feel the strikes accurately running through the chair when using a sword in *Final Fantasy*, or what feels like a spell being cast in *Hogwarts*. It embodies one of the great things about PC gaming, which is that it offers experiences you can't find elsewhere. Whether that's worth $300 is up to you and your wallet, but anyone who sits down to experience it will definitely leave impressed.

I'd love to see more sim-like games being supported, such as *Flight Simulator 2024* or *Forza Motorsport*, but for now the list of supported games is pretty limited. I'd also be a little bit concerned about the one-year warranty, which feels short for technology this new.

In the meantime, the Razer Freyja offers the usual high quality and innovation we expect from Razer, and works really well in the supported games. There are flaws such as that power cable, which I imagine will be ironed out as the tech develops, but if you're really into PC gaming, and have the money to spend on truly immersive gaming, the Freyja offers something unique. **–GUY COCKER**

VERDICT **7**

Razer Freyja

+ **GOOD VIBRATIONS** Excellent in supported games; Easy to install and remove; Comfortable.

− **PAIN IN THE ASS** High price; Short power cable; Limited game support.

$299, www.razer.com

SPECIFICATIONS

Power	Wired AC adaptor
Haptics Tactile Transducer	6 x Voice coil actuators
Connectivity	2.4 GHz Wireless, Bluetooth
Device Compatibility	PC, Android Mobile
Recommended User Height	5'2" - 6'6" (160–200cm)
Product Weight	6.6lbs (3kg)

Goemetric Future Model 5

Compact form factor arrives in a new era

GEOMETRIC FUTURE
MODEL
05
GEOMETRIC FUTURE

ONE OF OUR biggest bugbears at *Maximum PC* has been the lack of variety in the industry at large. It's a sad side effect of companies getting perhaps a little too big that they no longer want to take risks. There's a severe lack of innovation from the bigger brands, as they tend to chase market trends only once that trend has been established. It makes sense; you're trying to have smooth quarter-on-quarter consecutive growth with no drama, and wasting resources on products that might not light up the PC gaming community is a gamble. Still, it generally tends to lead to stagnation. There's no reason to push the boundaries of what we can do, and no late nights stressing over finer details trying to build an edge against your competition.

Time and time again, we've seen it happen, both in the PC-building industry and the wider world. It's competition and challenge that drive innovation, like the space race in the '60s or the Le Mans 66 with Ford and Ferrari. To put a more dour note on things, war generally leads to the greatest of technological innovations in the shortest amount of time.

A recent (and much lighter) example of that is the fishbowl chassis design trend that has swept the industry in this last year or so. First debuted by Lian Li with its PC 011 Dynamic line way back when, and then further capitalized on by the mad geniuses at Hyte, now almost every big manufacturer under the sun has their own fishbowl design: Corsair, Thermaltake, Phanteks, NZXT—the works. But it's all mild imitations of one another, really; unless you have some innovative design tweaks like NZXT or insane pricing like Phanteks, it's hard to stand out as a result.

Geometric Future, however, has done exactly that. It's continuing to push the limits of what's actually possible in this fishbowl design, and the Model 5 is exhibit A. So what makes it so special? Well, aside from the available color SKUs being absolutely wild (you get a standard gunmetal gray and white, followed up by a vibrant orange and our luminescent green), it's the internal layout that really revolutionizes the form factor.

This thing is small; seriously small (18.9 x 9.5 x 17.3 inches, to be precise). That's not exactly tiny until you realize it has the same dimensions as an average m-ATX tower case, but allows you to fit E-ATX motherboards, graphics cards up to 18.5 inches (460mm), and both a 420mm and a 360mm AIO simultaneously in here if you so desired, along with twin 2.5/3.5-inch hard drives. This is while retaining that fishbowl chassis design with all your internals on full display.

Geometric has managed this by effectively condensing the size of the PSU shroud in the chassis, and building it out into its own unique thing. It's an accent in the case, complete with power buttons, bold graphical elements, and some intelligent overall design.

There's support for an incredible 10 fans, and it comes with five 140mm RGB fans as standard in this config. There's built-in GPU support here too, plenty of ample cable management, and it's entirely toolless, with quality thick steel panels and tempered glass. There's a lot to love about it—and for the price, it's just outstanding. –**ZAK STOREY**

VERDICT
9
K!CK ASS!

Goemetric Future Model 5

+ FUTURE PROOF Outstanding price; Exceptional internal layout; 5x included 140mm RGB fans; Discrete GPU support built in; Innovative size.

− CHANGE FOR CHANGE'S SAKE Needs more tie down points; Plastic feet.

$150, www.geometricfuture.com

SPECIFICATIONS

Motherboard Support	ITX, Micro-ATX, ATX, E-ATX
2.5-inch / 3.5-inch Support	2 x 2.5 / 3.5-inch
Max Radiator Support	Up to 420mm Roof, 120mm Rear, 360mm Floor
Fan Support	3x 120/140mm Roof, 1x 120/140/160mm Side, 3x 120/140mm Floor, 1x 120/140mm Rear, 2x 120mm Motherboard Tray
Dimensions	18.9 x 9.5 x 17.3-inches
Graphics Card Clearance	18.5 - inches
CPU Tower Clearance	7.08 - inches
Warranty	1 year limited

The new characters in *Dragon Age: The Veilguard* just aren't as compelling as those from previous episodes.

© ELECTRONIC ARTS

ACTION ROLE -PLAYING

Dragon Age: The Veilguard

Nice action-RPG pivot, but what about the storytelling?

DRAGON AGE games have long faced the same problem as *Dragon Age* protagonists: the utter impossibility of pleasing everyone simultaneously. Arriving almost exactly a decade after *Inquisition*, with hopes and expectations as granular as demands for cameos from minor characters and RPG design preferences that go all the way back to 2009's *Origins*, *Dragon Age: The Veilguard* is indeed trying to please a lot of people.

The first 10 hours of *The Veilguard* are thus disorientating, even for a Thedas lore dork. It opens with the hero, Rook, and series fan-favorite dwarven archer, Varric Tethras, arriving in the city of Minrathous at the end of an apparently lengthy search to track down his Inquisition comrade turned elven god, Solas.

We stop Solas's world-ending ritual to tear down the barrier between the realm of magic and the rest of the world with a bit of action-movie guff—knocking a bunch of giant statues over—after which we assumed we would take a deep breath and get into the real adventure. Wrong.

The Veilguard does eventually slow down. It gave us a whole 70 hours of questing, companion bonding, and a lot of fun combat encounters. But EA has any number of studios who can make a fun action game. This is a BioWare game, and though it has the shape of one, with its lengthy companion journeys and world-saving plot, it falls short of the compelling choices and consequences the series has achieved in the past.

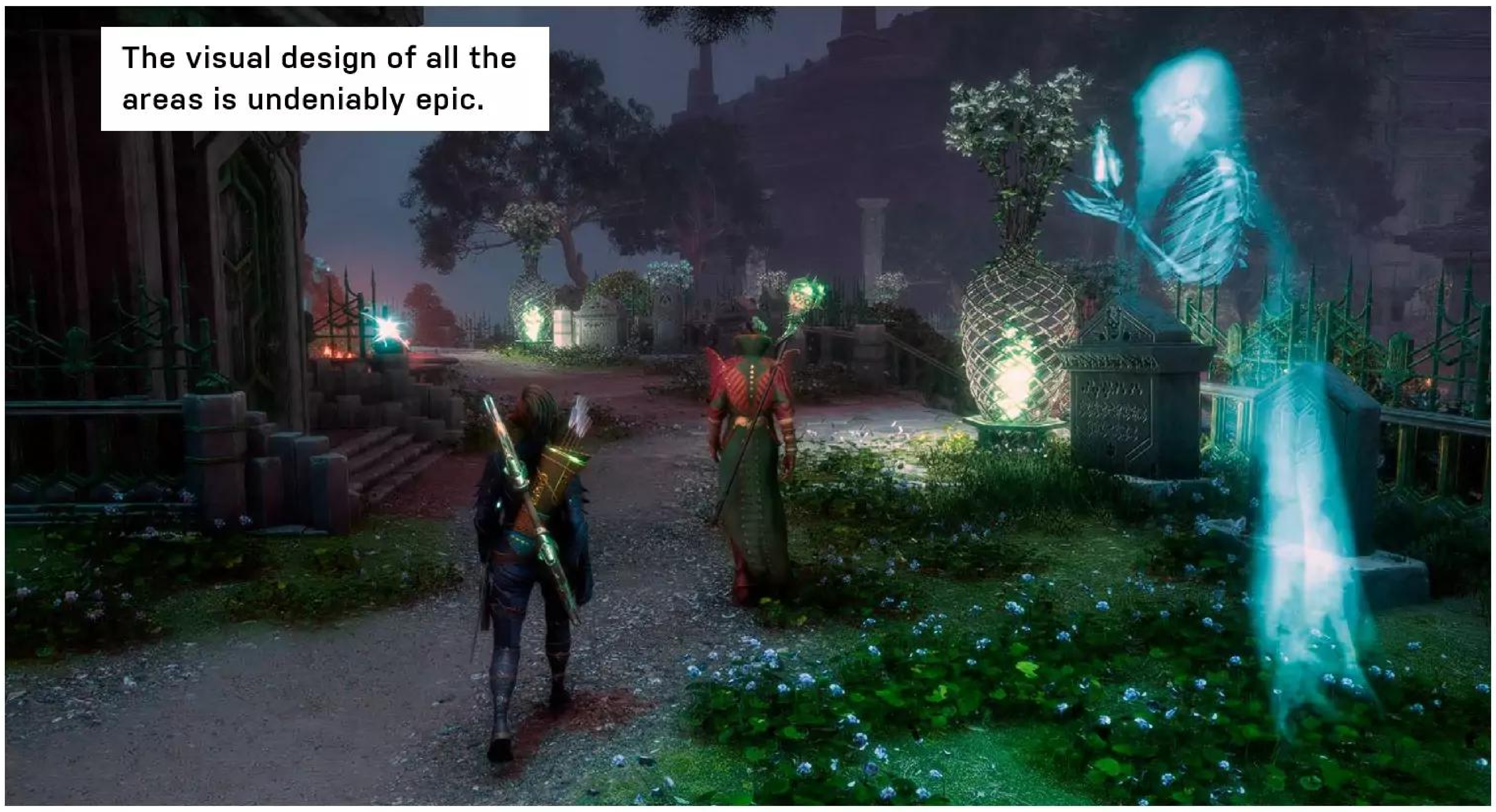
MIXED RESULTS

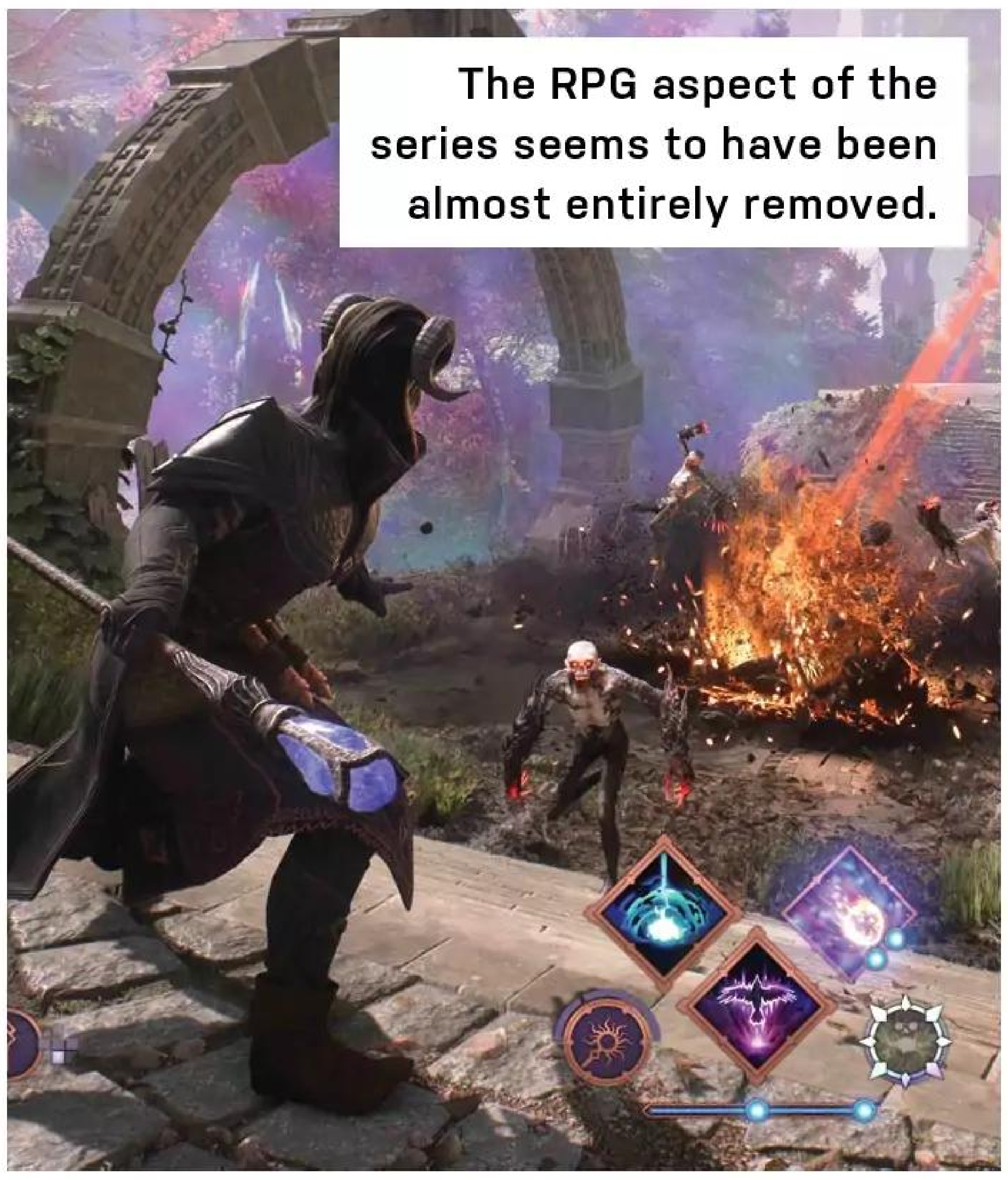
The Veilguard does catch its stride in the second act, tossing us a heap of side quests that encourage us to spend more time in each of its explorable zones and grant me enough time to appreciate all the things it genuinely does well, such as the incredible visual design of each area. It's also densely packed with fights that we're relieved to say are fast, snappy, and enjoyable.

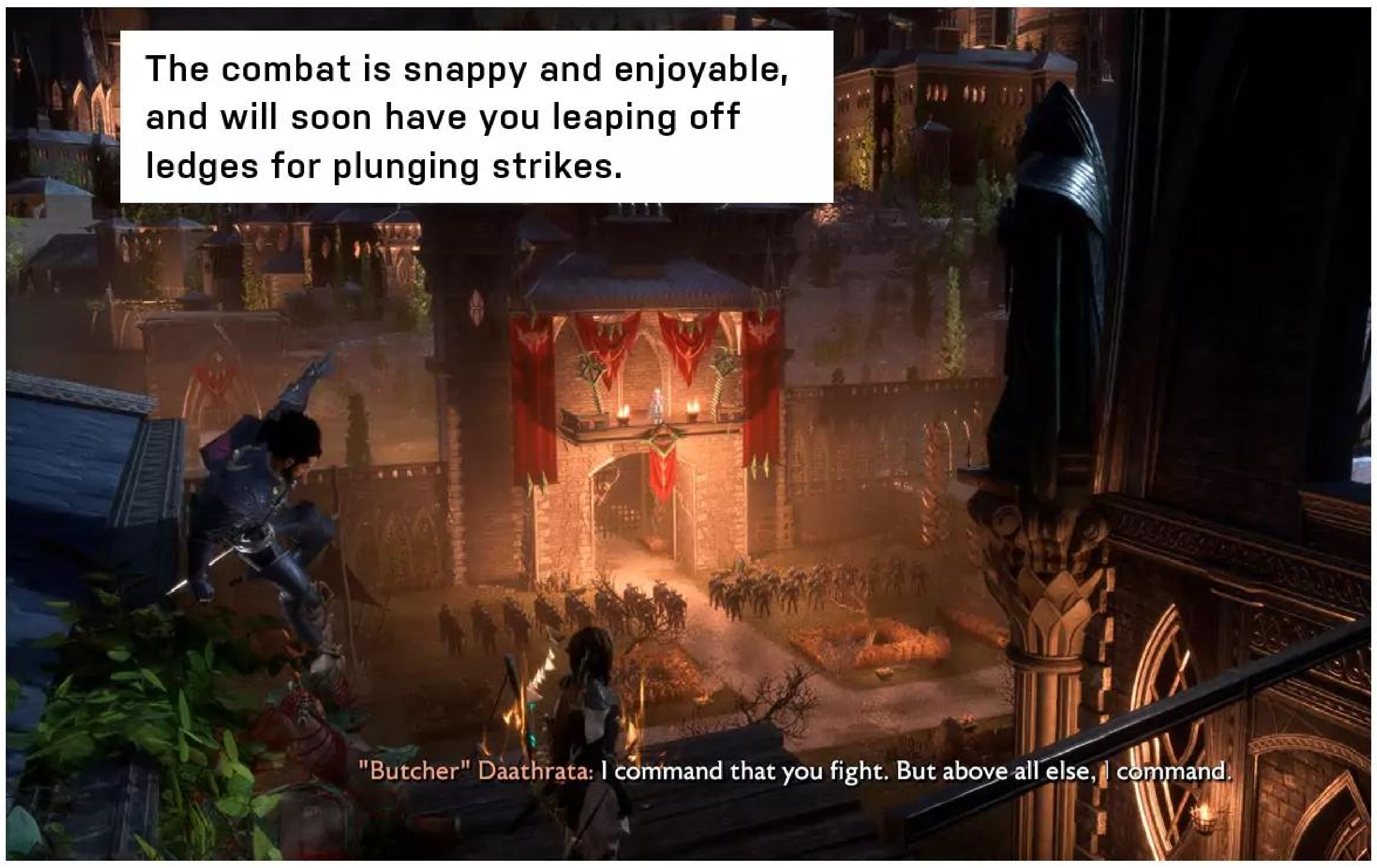
As a rogue, we weave together light and heavy attacks, sometimes holding a button longer to charge an attack and build up the stagger meter on an enemy. We dodge, parry, and leap off ledges for plunging strikes, and occasionally step back to take a headshot at an enemy mage with our bow. When we find our rhythm, we can even parry huge darkspawn ogres, and then use the ultimate ability to scatter a cluster of bombs on the ground.

There are a lot of other ways that *The Veilguard* has filed the rough edges off its RPG origins. There's effectively no inventory management, no carry weight limits, and no cost to respec our combat skills. Gear is all specifically tied to the character it's meant for, and each duplicate of a piece we collect automatically upgrades the one we've got to a higher tier of rarity and stats.

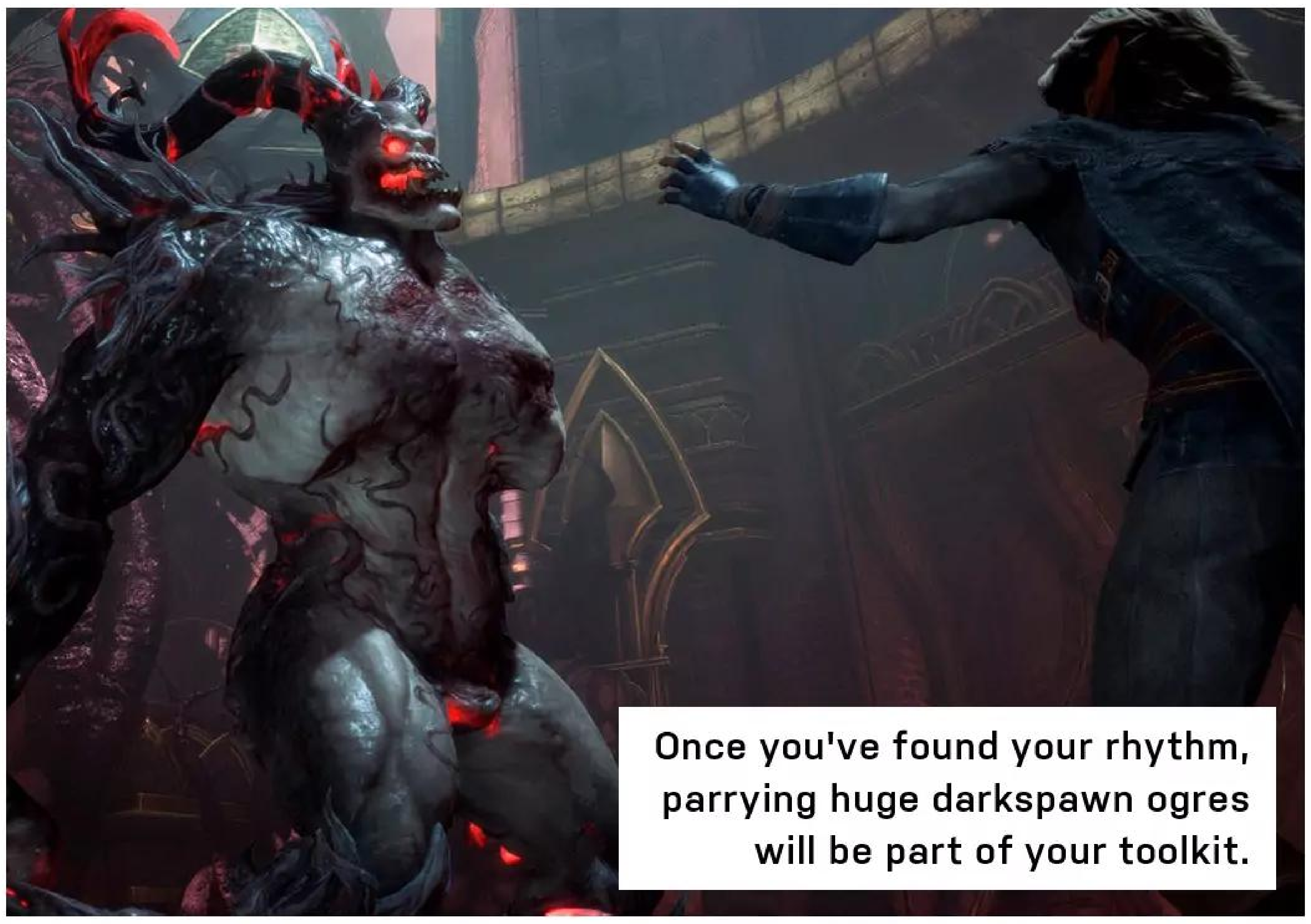
But it's a shame to get through a *Dragon Age* game and find that its characters and story are its weakest element. BioWare said that *The Veilguard* would prioritize "characters, not causes," and while we understand the sentiment that it doesn't want characters to be walking mouthpieces for ideals, it flew wide of the mark by not letting its characters have feelings about anything more complicated than 'the gods killing everyone is bad.' They don't have convictions that conflict with decisions we're making as their leader, and in fact put some of the biggest


The visual design of all the areas is undeniably epic.


The RPG aspect of the series seems to have been almost entirely removed.


"Butcher" Daathrata: I command that you fight. But above all else, I command.

The combat is snappy and enjoyable, and will soon have you leaping off ledges for plunging strikes.


Once you've found your rhythm, parrying huge darkspawn ogres will be part of your toolkit.

choices about their own personal journeys into our hands.

In the end, *The Veilguard* brings to bear a gauntlet of great battles and suite of spectacular cinematics to sell its final hours. Yet, it's telling that the most emotionally effective moments all come from the returning flawed heroes, not its own cast. The reveals and choices it goes out on could absolutely have destroyed us (a good thing). If only it had spent the rest of its time on characters and a plot that challenged us. –**LAUREN MORTON**

VERDICT
8

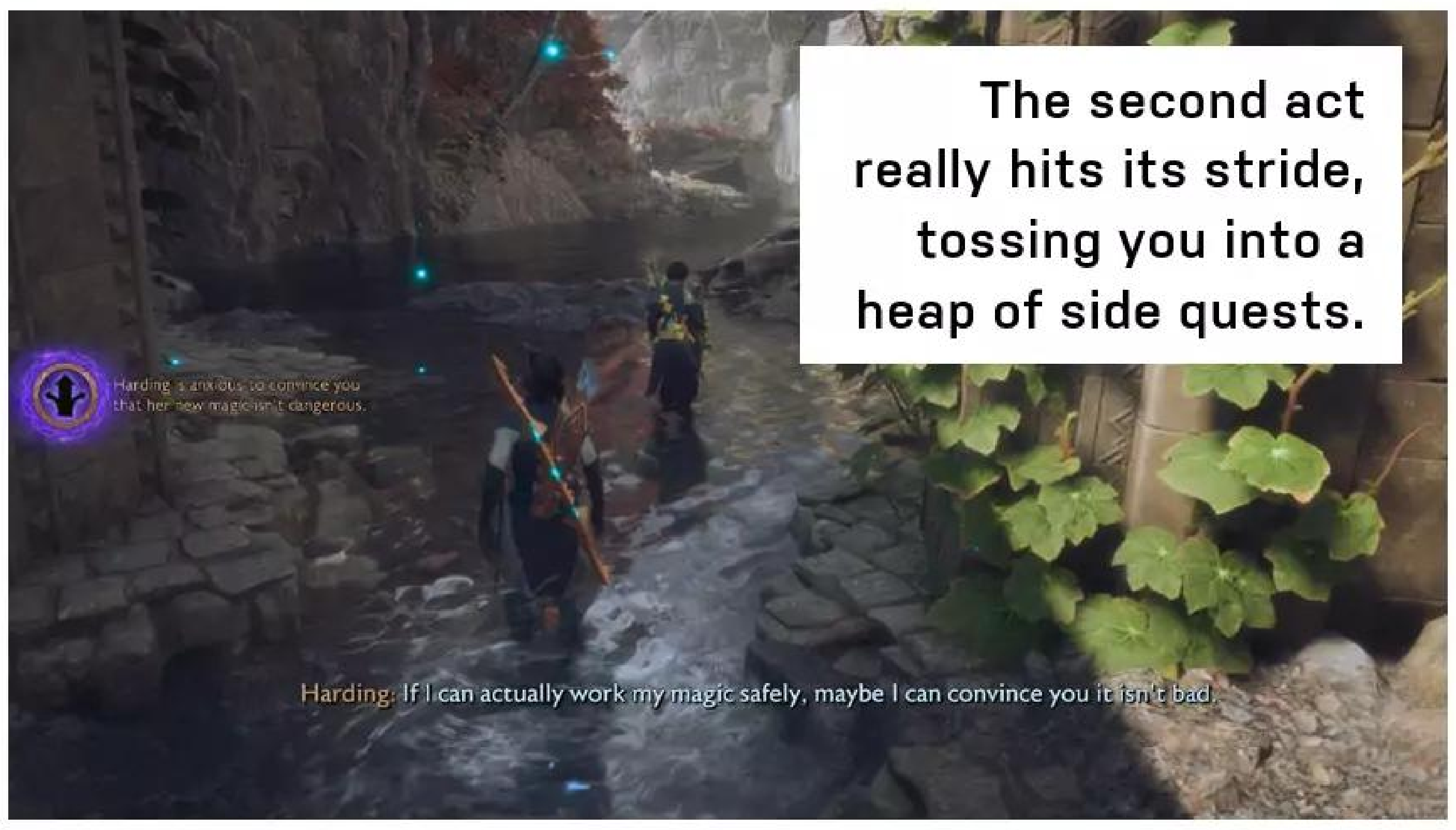
Dragon Age: The Veilguard

ROLL UP, ROLL UP Fantastic combat; Epic visuals; Plenty of side quests.

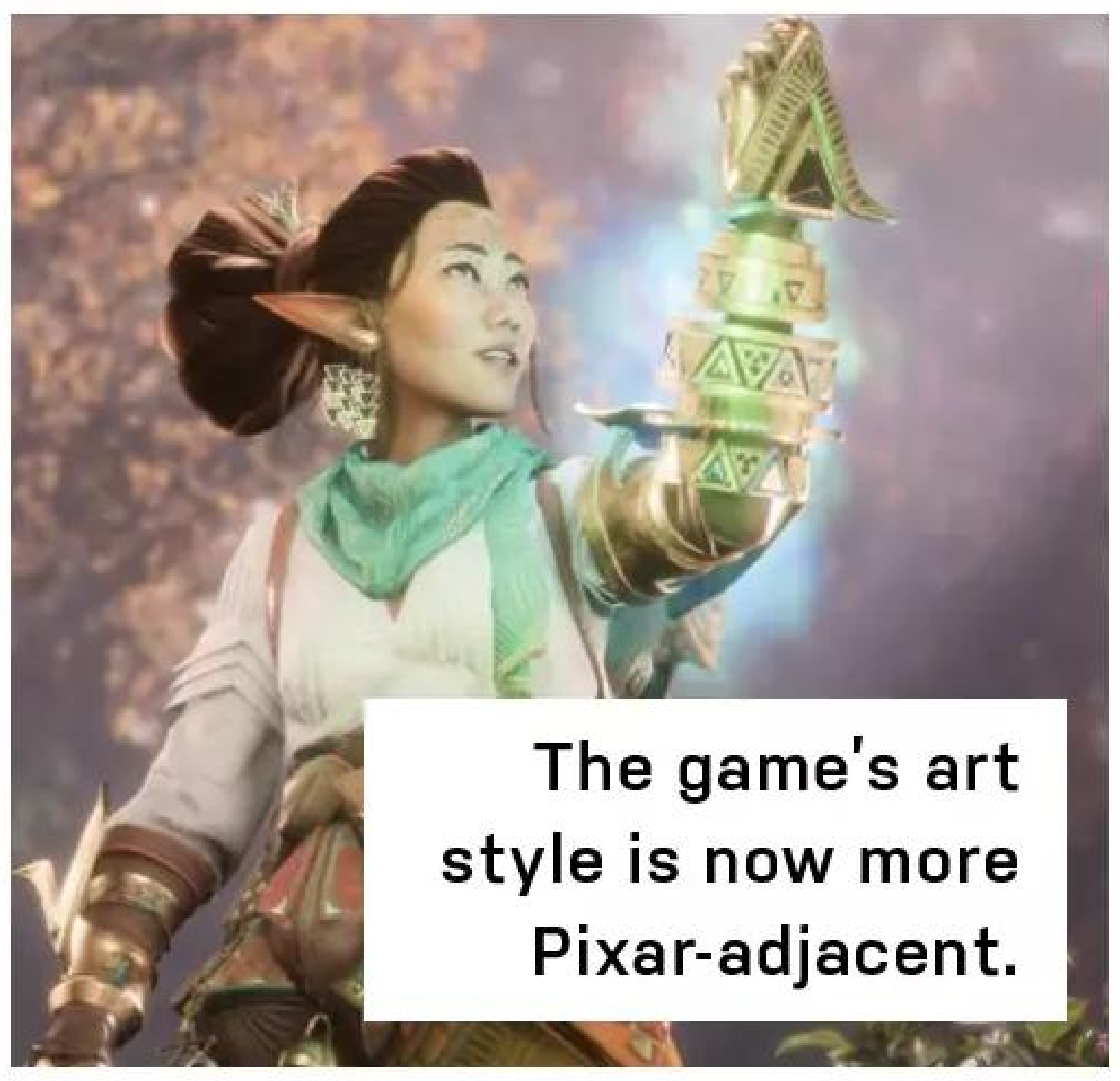
ROLL OVER New characters lack conviction; Slim on the storytelling front.

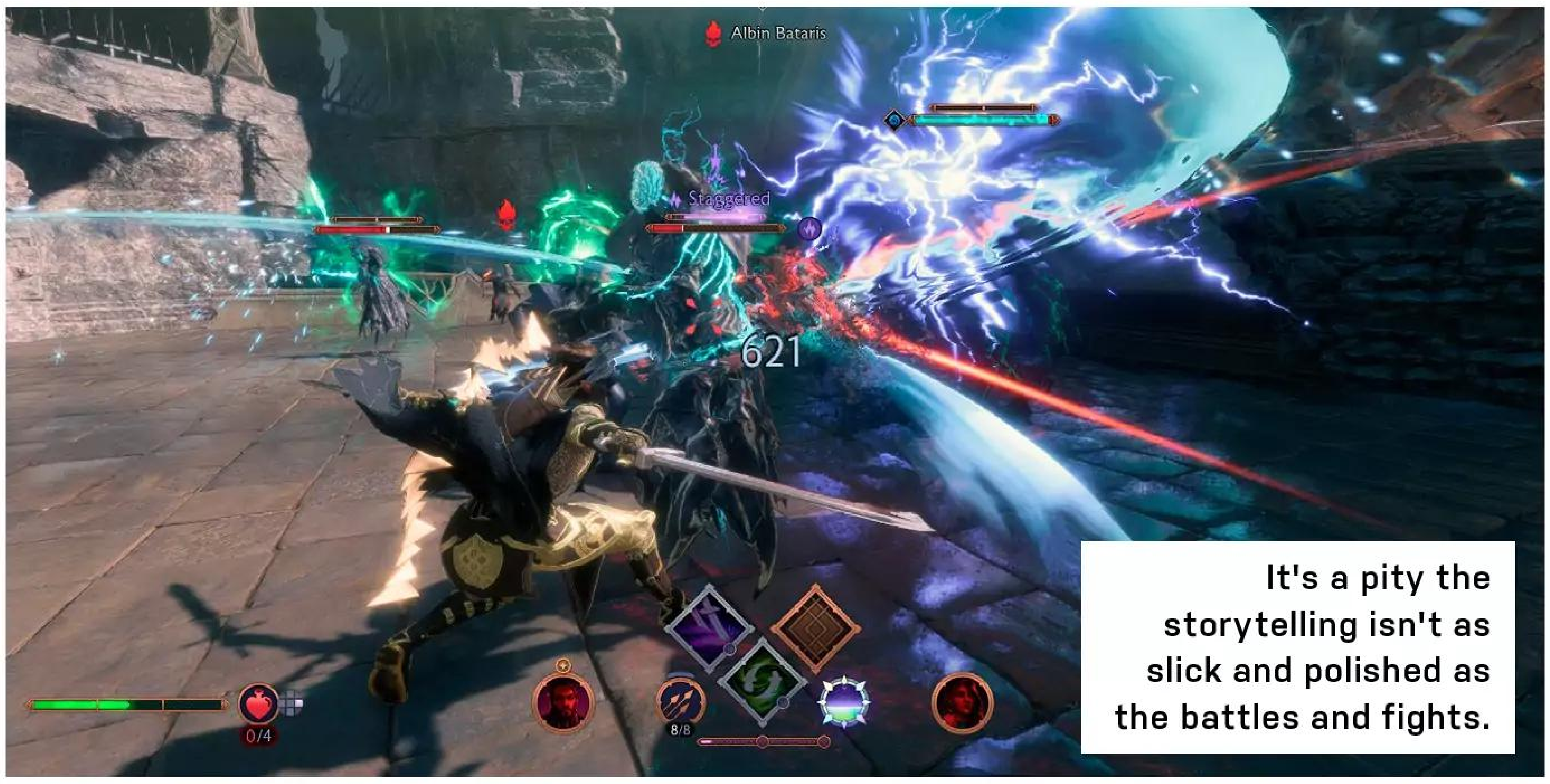
RECOMMENDED SPECS CPU, Intel Core i9-9900K / AMD Ryzen 7 3700X. GPU, NVIDIA RTX 2070 / AMD Radeon RX 5700XT. RAM, 16GB. OS, Windows 10/11.

$59.99, www.ea.com/en-gb/games/dragon-age/dragon-age-the-veilguard, M-rated 17+

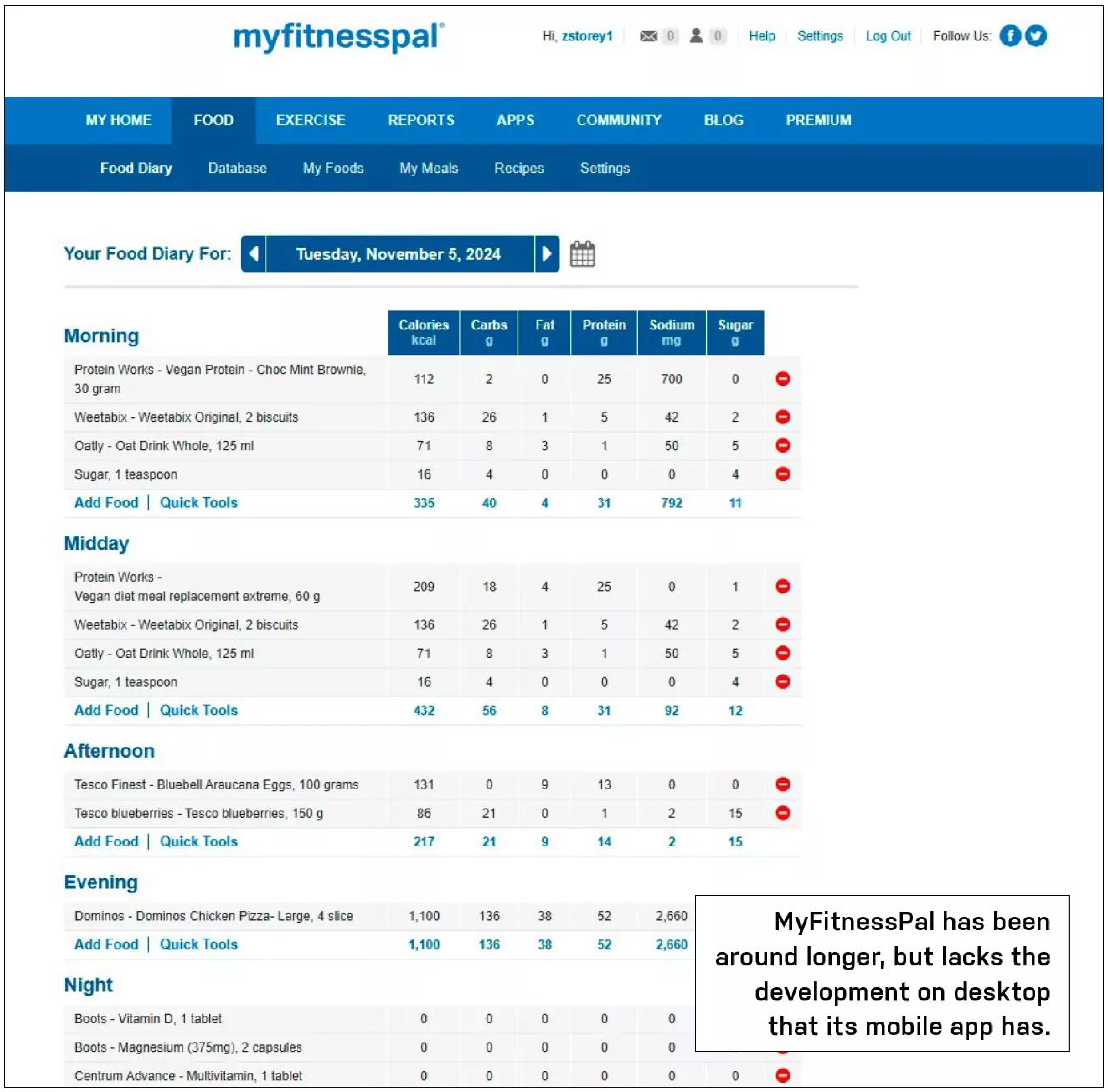

Harding: If I can actually work my magic safely, maybe I can convince you it isn't bad.

The second act really hits its stride, tossing you into a heap of side quests.


The game's art style is now more Pixar-adjacent.



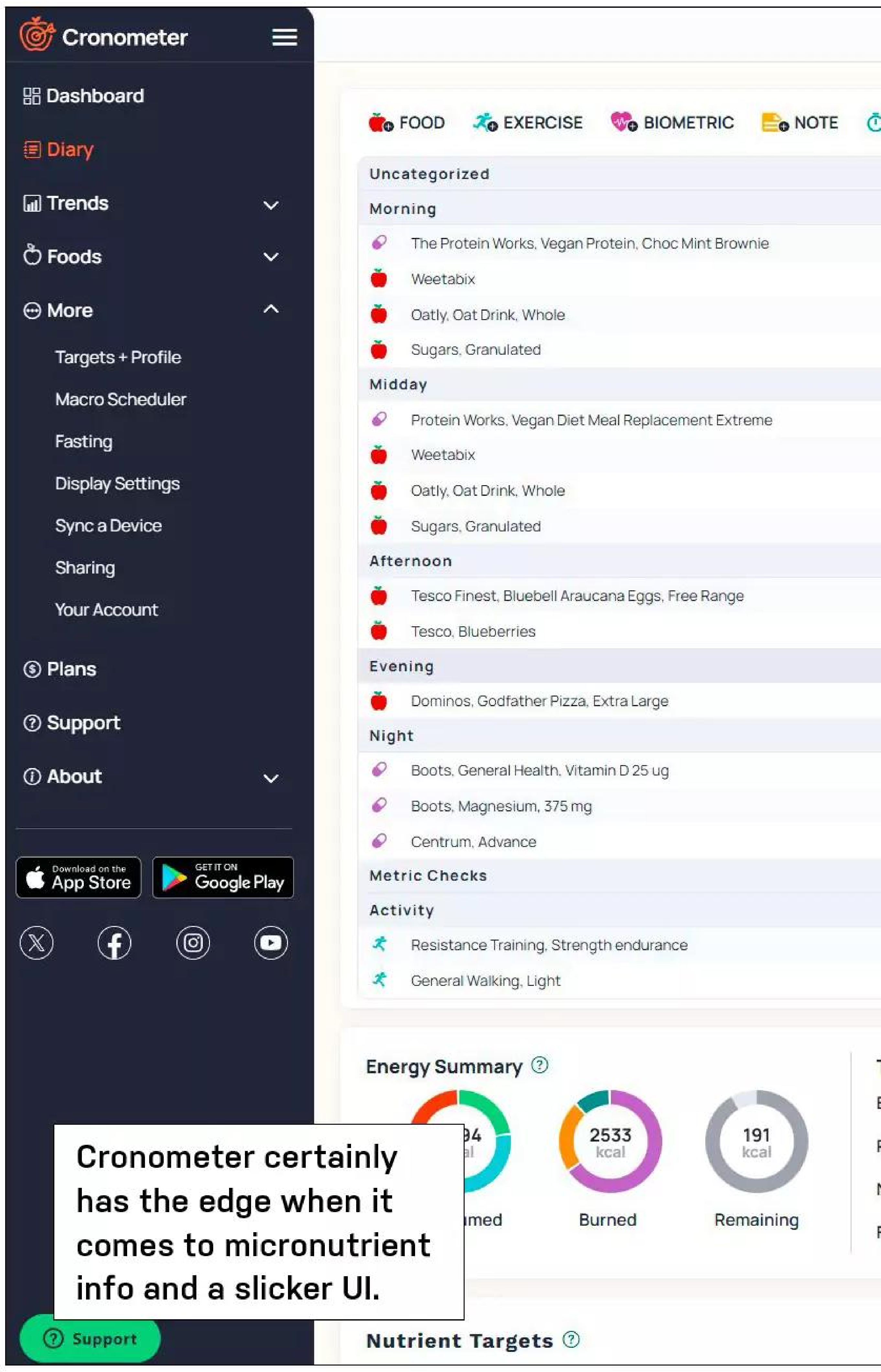
It's a pity the storytelling isn't as slick and polished as the battles and fights.



Your Food Diary For: Tuesday, November 5, 2024

Morning	Calories kcal	Carbs g	Fat g	Protein g	Sodium mg	Sugar g
Protein Works - Vegan Protein - Choc Mint Brownie, 30 gram	112	2	0	25	700	0
Weetabix - Weetabix Original, 2 biscuits	136	26	1	5	42	2
Oatly - Oat Drink Whole, 125 ml	71	8	3	1	50	5
Sugar, 1 teaspoon	16	4	0	0	0	4
Add Food | Quick Tools	335	40	4	31	792	11
Midday						
Protein Works - Vegan diet meal replacement extreme, 60 g	209	18	4	25	0	1
Weetabix - Weetabix Original, 2 biscuits	136	26	1	5	42	2
Oatly - Oat Drink Whole, 125 ml	71	8	3	1	50	5
Sugar, 1 teaspoon	16	4	0	0	0	4
Add Food | Quick Tools	432	56	8	31	92	12
Afternoon						
Tesco Finest - Bluebell Araucana Eggs, 100 grams	131	0	9	13	0	0
Tesco blueberries - Tesco blueberries, 150 g	86	21	0	1	2	15
Add Food | Quick Tools	217	21	9	14	2	15
Evening						
Dominos - Dominos Chicken Pizza- Large, 4 slice	1,100	136	38	52	2,660	
Add Food | Quick Tools	1,100	136	38	52	2,660	
Night						
Boots - Vitamin D, 1 tablet	0	0	0	0	0	
Boots - Magnesium (375mg), 2 capsules	0	0	0	0	0	
Centrum Advance - Multivitamin, 1 tablet	0	0	0	0	0	0

MyFitnessPal has been around longer, but lacks the development on desktop that its mobile app has.



Uncategorized

Morning
- The Protein Works, Vegan Protein, Choc Mint Brownie
- Weetabix
- Oatly, Oat Drink, Whole
- Sugars, Granulated

Midday
- Protein Works, Vegan Diet Meal Replacement Extreme
- Weetabix
- Oatly, Oat Drink, Whole
- Sugars, Granulated

Afternoon
- Tesco Finest, Bluebell Araucana Eggs, Free Range
- Tesco, Blueberries

Evening
- Dominos, Godfather Pizza, Extra Large

Night
- Boots, General Health, Vitamin D 25 ug
- Boots, Magnesium, 375 mg
- Centrum, Advance

Metric Checks

Activity
- Resistance Training, Strength endurance
- General Walking, Light

Cronometer certainly has the edge when it comes to micronutrient info and a slicker UI.

© CRONOMETER

MyFitnessPal vs Cronometer

Which reigns supreme in the world of diet tracking?

LOOK, WE GET IT, nutrition and fitness is a bit left field for *Maximum PC*—it's not something we often cover. That said, it's an integral part of all our lives, and the better we look after ourselves, the more time we can spend in good health with our loved ones, doing the things we enjoy (namely, tinkering with PCs). Staying inside of healthy weight ranges is one of the best and most effective ways of reducing the risk of all-cause mortality. It's almost at the level of being a complete panacea in a lot of measures.

The science has come a long way in recent years, so much so that we now have a far better understanding of how human metabolism works, how hormones and genetics affect it, and how best to manage it if you're aiming to lose body fat or gain muscle. In my case, I'm both a traditional field archer on weekends and a calisthenics enthusiast (body weight control) on weekdays. To improve my performance in both of those areas, it's imperative that I get physically stronger while controlling my weight. That means I need to keep a close eye on my nutrition and weight.

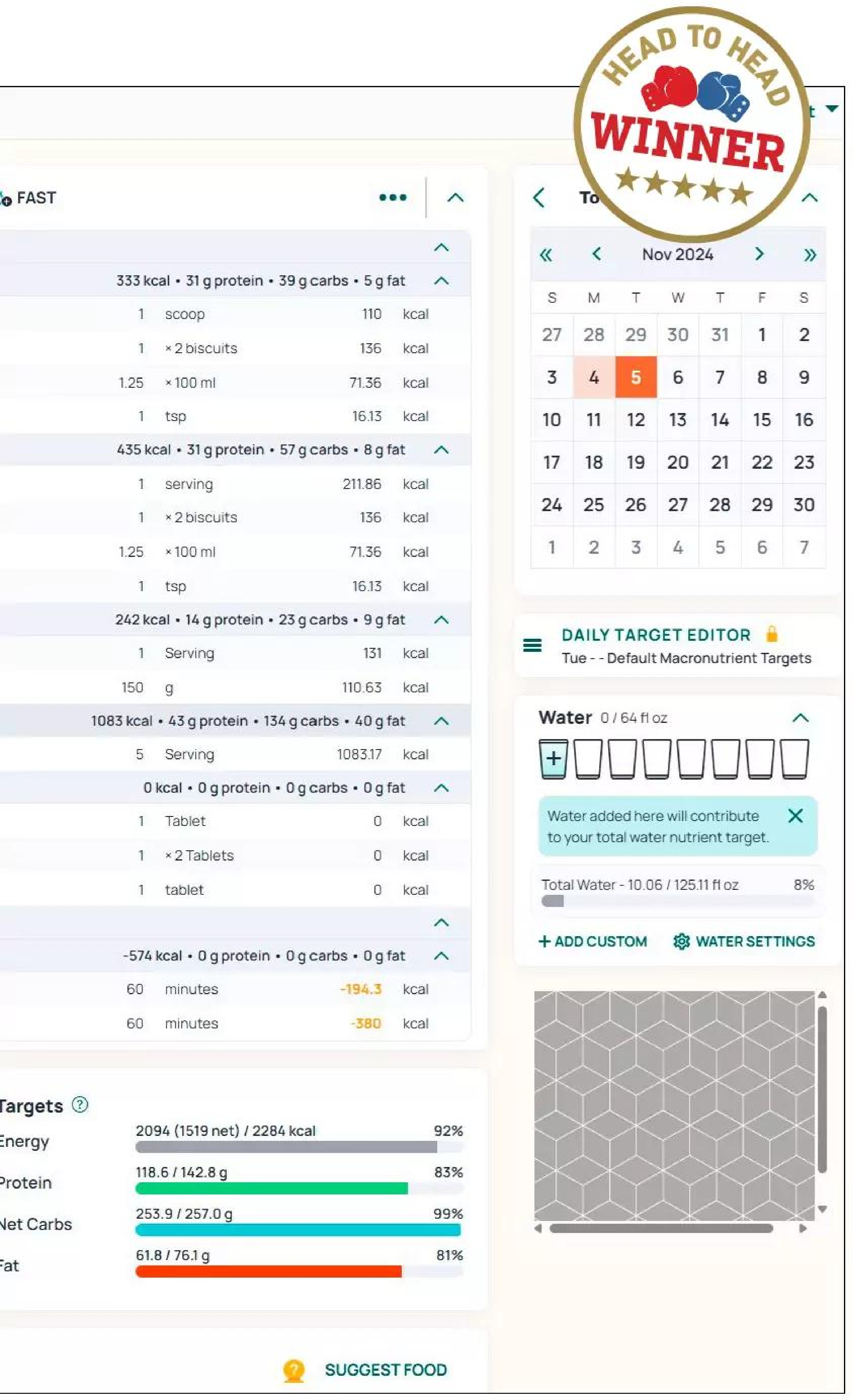
Fortunately, there's software and digital solutions out there that can help in this regard, the most famous of which being MyFitnessPal. It launched all the way back in 2005 as a simple website designed to allow users to track their daily calories and food intake. Developed by Mike Lee in 2009, it launched on iPhone, and since then has gone from strength to strength, becoming one of the go-to apps for those looking to keep tabs on their calories in and out.

In 2015, it was bought by sports and fitness apparel manufacturer Under Armour for an incredible $475 million, before being sold to a private equity firm in 2020. MyFitnessPal has an absolutely huge arsenal of features embedded into it, the most prominent and important of which being its food database. In short, you can effectively scan the barcodes of food to import them and their nutritional information into the app. From there, you can then count your macro-intakes along with calories, add exercise expenditure, and set weight targets.

Cronometer is certainly the underdog out of the two. Also established in 2005, built up as a side project by Aaron Davidson in British Columbia, it's called Cronometer as it was built around the 'calorie restriction optimal nutrition' diet. This basically involves reducing calorie intake while maintaining suitable vitamin, mineral, and macro amounts based on your own body weight.

SIDE-BY-SIDE COMPARISON

On the surface, both options provide very similar feature sets. Both have access to massive food databases globally; if you can think of a superstore food item, it's likely on there. Both have various forms of macro tracking, allow you to build custom recipes, and feature smartphone apps on Android and iOS, with connectivity



333 kcal • 31 g protein • 39 g carbs • 5 g fat

1	scoop	110	kcal
1	× 2 biscuits	136	kcal
1.25	× 100 ml	71.36	kcal
1	tsp	16.13	kcal

435 kcal • 31 g protein • 57 g carbs • 8 g fat

1	serving	211.86	kcal
1	× 2 biscuits	136	kcal
1.25	× 100 ml	71.36	kcal
1	tsp	16.13	kcal

242 kcal • 14 g protein • 23 g carbs • 9 g fat

1	Serving	131	kcal
150	g	110.63	kcal

1083 kcal • 43 g protein • 134 g carbs • 40 g fat

5	Serving	1083.17	kcal

0 kcal • 0 g protein • 0 g carbs • 0 g fat

1	Tablet	0	kcal
1	× 2 Tablets	0	kcal
1	tablet	0	kcal

-574 kcal • 0 g protein • 0 g carbs • 0 g fat

60	minutes	-194.3	kcal
60	minutes	-380	kcal

Targets

Energy	2094 (1519 net) / 2284 kcal	92%
Protein	118.6 / 142.8 g	83%
Net Carbs	253.9 / 257.0 g	99%
Fat	61.8 / 76.1 g	81%

Tue - - Default Macronutrient Targets

Water 0 / 64 fl oz

Water added here will contribute to your total water nutrient target.

Total Water - 10.06 / 125.11 fl oz 8%

© MYFITNESSPAL

and integration with all manner of step counters and smart watches.

The differences come in the form of how that data is represented, particularly on desktop, where, let's face it, we're most interested. Without a doubt, Cronometer has an edge here. Without paying for premium on either platform, Cronometer's overall UI is far cleaner and more intuitive. If you go into the food diary section of each, Cronometer's is impressively digestible. At the bottom, you'll not only find your overall macro targets in bright, bold bars, but also easily legible pie charts on calorie consumption.

The far more interesting segment comes below, however, where Cronometer goes on to break down the entire nutrition profile of your daily consumption, covering everything from vitamin and mineral intake, to the recommended daily allowances for those nutrients. Hover over those bars, and it'll even give you information on what each vitamin does, which foods are rich sources of them, and then tell you what foods you're eating that contain the most of that nutrient in your day's diary above—all on a singular page.

MyFitnessPal doesn't offer the same granularity that Cronometer does here, mostly focusing on Macros. You can get a report for the entire week, but you have to individually select each nutrient you want to look at, loading a new page in the process. It makes it far more awkward to analyze if you're into that kind of thing. It's worth mentioning that you can monitor these elements with MyFitnessPal, but it does require you to sign up to the premium package.

Both platforms do also support weight goals, and calorie reduction targets as well. However, in another win for Chronometer, it does present information in a much more legible way as you add directly into your food diary.

Speaking of food, MyFitnessPal does have a larger database of food items available to it, which can be helpful when dialing in your food diary; it uses a mixture of user-submitted and general-access databases, which is somewhat problematic, as it can often mean a lot of those items aren't actually calculated correctly. Crono, on the other hand, uses lab-analyzed databases instead, relying on NCCDB or the USDA for its nutritional information, among a few others. Both programs technically support barcode scanners as well on the mobile edition. However, that's now locked behind a premium paywall for MyFitnessPal, while its free on Cronometer. You can also create your own custom foods, but for Crono, as mentioned, that's locked to just you, so don't expect to find every McDonald's item on there unless you build them out yourself. Still, it's this accuracy that really gives Crono the edge.

PREMIUM COSTS

Both MyFitnessPal and Cronometer provide premium paid options. MyFitnessPal comes in at $20 per month, or $80 for the year (including a one-month free trial), and that adds that barcode scanner back in, along with custom macros, better insights, workout plans, repeat daily meal planning, and an absence of ads.

Cronometer is far cheaper in comparison, and has two tiers of subscriptions (Gold and Pro). Cronometer Gold, coming in at $8.99 per month, or $55 for the year, removes ads, allows you access to repeat items, introduces nutrition scores and macro schedules, fasting timers, and gives you a ton more insights and chart creation tools on the site itself. Both really do provide similar extras, although Crono does seem to have the edge here too, certainly on cost.

Cronometer also has a Pro variant. This is predominantly designed for personal trainers and those working in the health and fitness industry. This is more of a management tool for your athletes rather than a personal tool, letting you set meal plans, analyze nutrition, and chat with your clients through a secure messaging platform if needed.

DINNER TIME

Ultimately, this is a very one-sided fight. Cronometer is much further ahead of what MyFitnessPal has today, whether that's food database accuracy, micronutrient information, the UI experience, or even general pricing and the free experience. If you're keen to get a handle on your diet, and are looking for a place to get stuck in, or are just fed up with MyFitnessPal's lack of detail, then Cronometer is a good step up.

One thing we want to caveat this review with is that as always, ensuring you're safe with your nutrition is of tantamount importance. Nothing is ever going to be 100 percent accurate. You need to use this information as a reference point, not as an absolute be all-and-end-all. In the same way that we use Cinebench to indicate rough CPU rendering performance, the same should be applied to these kind of tools. Similarly, please always consult a trained and certified nutritionist or medical professional before you begin any radical diet adjustments. Treat these applications as measuring tools, and use the information and knowledge they provide to back up and achieve your fitness ambitions without letting it control you. Bit of a serious tone, we know, but it's something that we felt needed addressing.

–ZAK STOREY

VERDICT
7

MyFitnessPal

+ CONTROLLED CALISTHENICS Simple design; No fluff, and easy to use; Integrates with smart devices a touch better.

− EGO-LIFTING Inaccurate food database; Poor web UI; Paid sub required for basic features; Limited nutritional information.

$19.99 per month / $79.99 per year,
www.myfitnesspal.com

VERDICT
9
KICK ASS!

Cronometer

+ SCIENCE-BACKED NUTRITIONAL ADVICE Top-tier UI; Far better pricing; Barcode scanner is free; Nutrient tracking far more advanced; Premium suite adds a lot of extra detail.

− EVERYTHING IS POISON TIKTOKER Occasional trouble sharing exercise info across devices.

$8.99 per month / $55 per year,
www.cronometer.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Monitor upgrades
> Intel concerns
> Physical feedback

The Alienware AW3423DWF: once you've gone OLED, it's hard to go back, despite the occasional drawback.

HDR or bust?

After years of reading about the supposed benefits of HDR visuals, I've finally decided to see what all the fuss is about. I have a decent gaming rig with a Ryzen 7800X3D and an RTX 4080, but I've never really splashed out on a gaming monitor.

So, I'm finally going to make the jump from a regular SDR monitor to something with HDR capability. But do I need to fork out for a pricey OLED panel, or can LCD monitors get the job done?

Thanks in advance.

– J. Cunningham

CONTRIBUTOR, JEREMY LAIRD, RESPONDS: Okay Jim, this one is actually pretty straightforward. If you want to experience HDR visuals, there's only one real option: you need an OLED monitor.

It's true that various flavors of supposedly HDR-capable LCD monitors are available, many of them for a lot less money than OLED. But they're also all various flavors of you-know-what. Entry-level LCD HDR monitors that lack local dimming aren't HDR at all; they're just a bit brighter than a standard LCD, and might have better color coverage.

Step up to an LCD with full-array local dimming, and you'll get a screen that's technically capable of HDR. But even the highest-resolution backlights are very, very low precision. Allow me to explain just how low precision.

Let's say you have a 4K 'HDR' monitor that has a full-array backlight with 1,154 zones. Sounds kind of impressive, right? In fact, each zone lights up over 7,000 pixels. Put another way, the backlight will have a resolution of about 40 by 25 pixels. That is super blocky, and means the backlight can't possibly map accurately to details on the screen. You're always going to have some parts that are too bright and washed out, while others will be too dark, crushing detail.

At the same time, you've introduced the complexity of an algorithm, trying to decide what compromises to make in order to minimize all that. In short, it doesn't work, and it's a horrible kludge.

By contrast (pun intended), OLED panels offer perfect per-pixel lighting control. You can have a maximum brightness white pixel next to a totally black pixel. Once you've tried OLED, you won't want to go back to an LCD when it comes to the HDR experience. This is particularly true of games, which look their very best on an OLED monitor.

Of course, OLED does have its own issues. Full-screen brightness is still a weak point, and there's the ever-present worry of burn-in. But ultimately, if you want a true HDR experience, it's the only way to go.

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: As Jeremy says, go OLED or go home. I've had the ultrawide Alienware AW3423DWF for the last two years, and haven't looked back, at least when it comes to gaming, anyway—it's really hard to go back to a non-OLED display after playing

↘ submit your questions to: editor@maximumpc.com

Cyberpunk 2077 on one of these things.

However, I will admit that there are some annoyances: the message that comes up on my screen three times a day telling me to do a pixel refresh, which I sometimes adhere to, but more often than not ignore; the lack of overall brightness for daily tasks like work (and indeed writing my response to this letter), and the slight lack of sharpness on text.

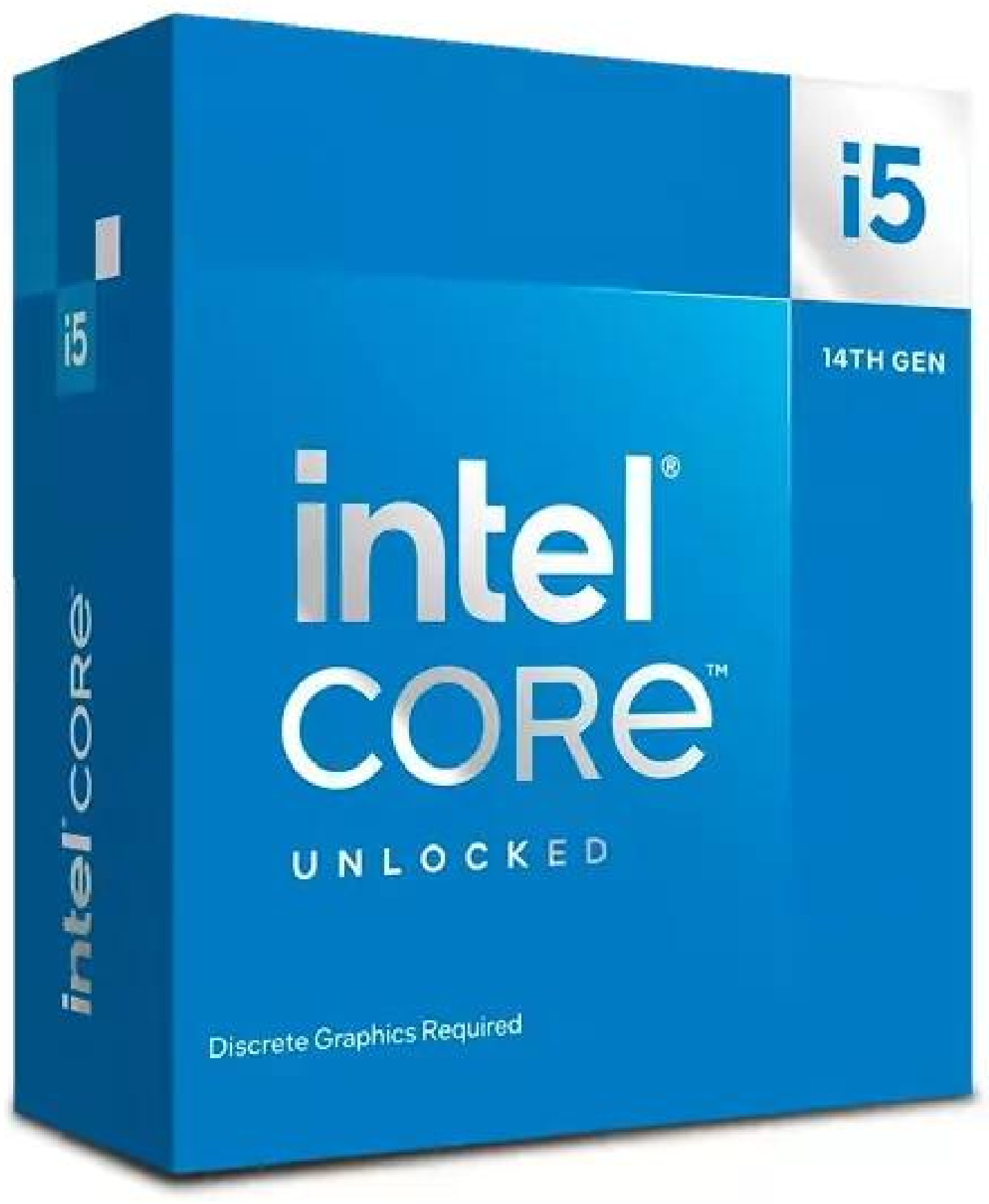
But again, gaming on an OLED is just so good, I don't really think about those issues much.

Has Intel really fixed Raptor Lake?

I'm still on an Intel 10th-gen CPU, which has been mostly fine for the last four years or so. But I've just noticed that Intel has given its 14th gen CPUs a big price cut, thanks to the arrival of its new Core Ultra desktop chips. $230 for a Core i5-14600KF looks pretty darned attractive to me. But I'm concerned—has Intel actually fixed those old 14th Gen processors? Would you guys buy one with your own money? —**M. Gonzalez**

CONTRIBUTOR, JEREMY LAIRD, RESPONDS: This is a very tough question. In testing, Intel's microcode patches (issued via motherboard updates) do indeed seem to have solved the voltage spike issues at the root of the 13th and 14th gen Core CPU instability problem. That should mean that any new chip you buy today ought to be safe.

Whether existing chips that have already run for a time with the old microcode have been damaged and to what extent is a much harder call. Of course, even with a new CPU, it's impossible to be 100 percent certain, so it all comes down to a risk-reward calculation.



Now's a great time to grab a bargain on an Intel 14th-gen CPU. But should you?

Is the 14600KF now cheap enough to be worth the risk? That's a yes, at least in our opinion. But it is frustrating that it's still a yes with caveats.

One thing I will say is that the value proposition here, if it exists, definitely feels like it works better at the lower end. The 14600KF for just $230 is an awful lot of gaming CPU for the money, and the slight risk that Intel hasn't totally resolved those 13th and 14th Gen issues is arguably well priced at that level. Also, Intel does offer an extended warranty if you're concerned about future issues, although opening up your PC and then having a system you can't use during that period is obviously not ideal.

For sure, there are some nice deals further up the Raptor Lake range. The 14700KF is yours for $328, for instance, and the 14900K flagship can be snagged for $443, but I'd be far less inclined to take a risk on those chips.

Put simply, the more you fork out, the less appealing it is to run that small, hard-to-fully-quantify risk that Intel hasn't solved the 13th and 14th Gen CPU crashing issues. Ultimately, your attitude to that risk is going to be a personal thing. But now you know those 14th Gen chips have just got a whole lot cheaper, and the choice is yours.

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: The 14600K is the chip I've been running in my personal machine for the last year or so since it came out. On a purely anecdotal level, I've had no issues at all with the chip, although I have been keeping an eye on NZXT's website for all the new BIOS updates, and then updating my Z790 motherboard whenever a new one is available, which I admit has proved to be a little tiresome.

As Jeremy says, this 14th gen mid-range chip is a gaming champ, and as you can bag a real bargain on one right now, it'd be my preference over the new Core Ultra 5 245K (reviewed on page 76). However, I say this as a journalist with access to lots of other CPUs if things ever go wrong. If I was a consumer, using a 14th-gen chip in a PC that I also used for time-critical work, and perhaps without a backup laptop or other machine, I'd probably steer clear and go for a CPU that I wouldn't be worried about failing on me.

I really applaud your eye for a bargain, though—we obviously jump on new gear as soon as it's available to put it through its paces, but out in the real world, I'd nearly always advocate for the arrival of a new generation being a great time to grab a bargain on the previous-gen hardware.

Haptic happiness?

I just read your evaluation of the Razer Freyja haptic chair (December 2024, page 73). It's very interesting, but I'd also love to see a review of Cooler Master's Motion-1 from your esteemed publication, and others if anyone else is doing anything similar.

Keep up the good work!

– M. Plante

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: I know that it's only one letter, but I didn't realize there were fans of haptic feedback chairs out there that we weren't catering to! I think it's perhaps because I see these kinds of things at trade shows like CES in Las Vegas, and then I get home and kind of forget they exist, just because I sadly don't have space in my small apartment for specialist chairs or racing/flight setups.

The Razer Freyja is indeed a cool concept, and one that I've enjoyed using when I get the time to unwind and play some games. It definitely makes titles like *Hogwarts Legacy* feel more immersive, and I even enjoyed sitting there and listening to music in it, but I think all of that is negated somewhat by the $300 price tag, which is the sort of money I'd always rather spend on a premium game controller or headset, both of which Razer also make with great haptic feedback.

In terms of the Cooler Master Motion-1, that's not a chair I was even aware of, if I'm totally honest. I always attend Cooler Master's suite at CES in Las Vegas, so I must have seen it at some point, as I did try an amazing *Microsoft Flight Simulator* rig of theirs earlier this year. The Motion-1 looks like a cross between a traditional gaming chair and one designed for racing sims, which makes sense, as it uses haptic technology from D-Box, whose chairs I used a long time ago when I visited Codemasters' racing studio in England.

I'll reach out to Cooler Master and see them again at CES in January, but if you're a haptic chair manufacturer and are reading this, please feel free to get in touch! ⏻

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THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

WELL FOLKS, there we have it: two whole new generations of processors, and well, we're still recommending the last generation across the majority of our builds. It's a little bit wild out there right now. What's the big holdup, then? Why aren't we jumping ship to Intel and AMD's latest and greatest? Simply put, it's all a matter of price. Right now, both Team Blue's 14th gen and Team Red's 7000 series have been hit with a serious RRP hammer; the numbers don't lie, and we've seen price drops of well over $100 in some cases over the last few months. This is, of course, intended to try and shift the remaining stock out of Intel and AMD's warehouses, yet bizarrely, given how little extra performance you're getting with the new chips, it has had the effect of making the older chips insanely good value for money. Weird, huh?

Our budget builds, then, have seen very little change outside of us just trying to hold on to those prices wherever we could. We've shifted both builds over to a new 650W EVGA PSU, in the process bumping up that maximum capacity by 50W in anticipation of new GPUs potentially drawing more juice in the coming months, but otherwise, there was very little that needed shuffling around. Pricing sort of flattened out between the two of them. Our AMD system in particular was an example of this, coming in at just $9 less than it was last month.

Our Intel system had a touch more trouble; our motherboard of choice from last issue had its price bumped up, and although there are cheaper boards to be had out there, to give it some parity with our AMD system, we decided to grab an ATX motherboard instead. That did bump the overall price up by a total of $32, but it's well worth it for the extra connectivity (and a healthier-looking system).

AMD INGREDIENTS

PART		PRICE
Case	Phanteks XT View	$84
PSU	650W EVGA 650BP 80+ Bronze **NEW**	$55
Mobo	MSI PRO B650-S Wi-Fi	$130
CPU	AMD Ryzen 5 7600	$188
GPU	ASRock Challenger D Arc A750 8GB	$190
RAM	32GB (2x 16GB) Silicon Power XPOWER Pulse Gaming @ 6,400 C32	$88
SSD 1	500GB Crucial P3 Plus PCIe 4.0 M.2	$41
SSD 2	1TB Kingston NV2 PCIe 4.0 M.2	$55
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$863**

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks XT View	$84
PSU	650W EVGA 650BP 80+ Bronze **NEW**	$55
Mobo	Gigabyte B760 DS3H AX **NEW**	$140
CPU	Intel Core i5-14400F	$176
GPU	ASRock Challenger OC RX 7600 8GB	$250
RAM	32GB (2x 16GB) Silicon Power Value Gaming @ 6,000 C30	$88
SSD 1	500GB Crucial P3 Plus PCIe 4.0 M.2	$41
SSD 2	1TB Kingston NV2 PCIe 4.0 M.2	$55
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$921**

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MID-RANGE

FORTUNATELY FOR US (having no product changes to talk about puts a dampener on the write-up for these builds), our AMD and Intel systems in the mid-range have had a few changes for us to chat shop about. Interestingly, both rigs had motherboard and GPU swaps to help mitigate some rather hefty price hikes.

Our AMD build in particular saw a $94 price hike on the ASRock X670E Pro RS from last month, so we've opted to go with its newer X870 sibling instead, which ironically is $10 cheaper than last month's pick. Plus, with this change, you won't need to update the BIOS to get it running, which certainly helps. We've also swapped out from the Gigabyte Gaming RX 7700 XT for XFX's Speedster SWFT 210 Core variant instead. Although the Gigabyte card didn't see a major increase in price, we've done this to offset a few other price hikes in our mid-range setup.

As for Intel, it was exactly the same problem; the GPU and motherboard both received price bumps, with the Pro Z790-S from last month shooting up by $30 and our MSI Ventus 2X RTX 4070 bouncing up to $545. Not ideal, but again, we managed to snag a few good bargains. The MSI Pro Z790-VC WiFi managed to slide in at just $150 (the same motherboard price point that we had last month), and we spotted PNY's XLR8 Gaming Verto Epic-X RGB RTX 4070 for an outstanding $500, bringing the price down by $20 compared to last month (there must be a manufacturer competition for who's got the most ridiculous product name).

Both systems have received a nice uptick in SSD performance, too; we've ditched Lexar's NM790 for Corsair's MP600 Elite. That packs in some lovely Kioxia 162-layer TLC NAND with Phison's E27T controller to deliver top-notch performance for our needs here. Price changes? AMD's up by $7 on last month, and Intel's down by $3. And yep, the AMD build here is the only one in this month's Blueprints with a current-gen chip in it.

AMD INGREDIENTS

PART		PRICE
Case	Hyte Y40 ATX Mid Tower	$122
PSU	850W Thermaltake Toughpower GF1 2024 80+ Gold	$91
Mobo	ASRock X870 Pro RS **NEW**	$200
CPU	AMD Ryzen 7 9700X	$320
Cooler	Noctua U12S chromax.black	$90
GPU	XFX Speedster SWFT 210 Core RX 7700 XT 12GB **NEW**	$390
RAM	32GB (2x 16GB) TeamGroup T-Create Expert @ 6,400 C32	$95
SSD 1	1TB Corsair MP600 Elite w/Heatsink M.2 PCIe 4.0 SSD **NEW**	$70
SSD 2	2TB Silicon Power UD90 M.2 PCIe 4.0 SSD	$95
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,505**

INTEL INGREDIENTS

PART		PRICE
Case	Hyte Y40 ATX Mid Tower	$122
PSU	850W Thermaltake Toughpower GF1 2024 80+ Gold	$91
Mobo	MSI Pro Z790-VC WiFi **NEW**	$150
CPU	Intel Core i7-14700F	$317
Cooler	Enermax Liqmax III 360 ARGB 360mm AIO	$80
GPU	PNY XLR8 Gaming VERTO EPIC-X RGB RTX 4070 12GB **NEW**	$500
RAM	32GB (2x 16GB) Silicon Power Xpower Zenith Gaming @ 6,000 C30	$85
SSD 1	1TB Corsair MP600 Elite w/Heatsink M.2 PCIe 4.0 SSD **NEW**	$70
SSD 2	2TB Silicon Power UD90 M.2 PCIe 4.0 SSD	$95
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,542**

TURBO

GEOMETRIC FUTURE
MODEL
05
GEOMETRIC FUTURE

ANYONE BEEN WATCHING the latest season of *Arcane* lately? Seriously good, that. Okay, enough stalling. Yes, we've made one change to both of our Turbo builds this month, and that's on the primary OS SSD for these builds. We've ditched MSI's Spatium M570 HS for Crucial's T700 instead. Both of them are PCIe 5.0 drives, and basically come with the same hardware, but the MSI SSD saw a price hike of $40 over last month. The T700 didn't exactly escape that NAND hike either, but it's only $10 more than last issue, and it is one of the best PCIe 5.0 SSDs that we've tested to date—second only to the T705.

Why no changes otherwise, though? Well, let us reel off the AMD price drops for you here: PSU down by $10, motherboard by $15, CPU by $43, GPU by $10, RAM by $2, and the SSD 2 was stable with no change as well. The only price increases came in the form of the Kraken 360 going up by $14 (yet it's still one of the most affordable 360mm AIOs out there), and the chassis went up by $25, although again, you can grab that in the fanless configuration for $110, or one of the other colorways for $150, if you're looking to save some dollars. Overall, those price shuffles have brought the AMD build down by an impressive $31 on last issue. It's not a huge amount, all things considered, as it's still $2,541, all in all, but it still comfortably sits around our $2,500 price tag target that we aim for with these builds.

Intel, however, wasn't quite so lucky. In an almost antithetical phenomenon compared to our AMD build here, it saw significant price bumps across the range. The CPU went up by $21, the cooler by $25, and the SSD shift has brought it up by $10 more as well. Not helpful. There were a couple of wins; the motherboard, PSU, and GPU fell in price, but not by any huge margin. Annoyingly, the 14900KF and the K variants are priced about the same here, and without dropping to a 14700K, there's little price shaving to be done. Plus, the Core Ultra 9 285K is still near $180 more than this one currently; never mind the motherboard pricing.

So yeah, it's still the best value turbo Intel build you can get right now. That said, it's gone up by $51 from last month.

AMD INGREDIENTS

PART		PRICE
Case	Geometric Future Model 5	$160
PSU	Super Flower Leadex VI Platinum Pro 1,000W 80+ Platinum	$120
Mobo	MSI MAG X670E Tomahawk Wi-Fi AM5	$229
CPU	AMD Ryzen 9 7950X	$487
Cooler	NZXT Kraken 360 360mm AIO	$160
GPU	ASRock Phantom Gaming OC Radeon RX 7900 XTX 24GB	$840
RAM	64GB (2x 32GB) Patriot Viper Venom @ 6,400 C32	$168
SSD 1	2TB Crucial T700 PCIe 5.0 M.2 **NEW**	$210
SSD 2	2TB Lexar NM790 PCIe 4.0 M.2	$135
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $2,541

INTEL INGREDIENTS

PART		PRICE
Case	Geometric Future Model 5	$160
PSU	Super Flower Leadex VI Platinum Pro 1,000W 80+ Platinum	$125
Mobo	Asus Prime Z790-A Wi-Fi	$250
CPU	Intel Core i9-14900KF	$439
Cooler	Asus ROG Strix LC II ARGB 360mm AIO	$155
GPU	PNY Verto Overclocked RTX 4080 Super 16GB	$990
RAM	64GB (2x32GB) TeamGroup T-Create Expert @ 6,000 C34	$160
SSD 1	2TB Crucial T700 PCIe 5.0 M.2 **NEW**	$210
SSD 2	2TB Lexar NM790 PCIe 4.0 M.2	$135
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32

Approximate Price: $2,656

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